CONNECTICUT DEPARTMENT OF TRANSPORTATION
Reconstruction of I-84
Washington Avenue to Pierpont Road
Waterbury, CT
ConnDOT Project No. 151-273
Federal Aid Project No. NHI-84-2 (172) 33

FINAL SCOUR REPORT
PEDESTRIAN BRIDGE CROSSING
OVER THE MAD RIVER

Waterbury, Connecticut

Prepared By:

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July 2006
Revised May 2014

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Executive Summary

This Scour Report has been prepared for the final design of a pedestrian bridge crossing over the Mad River, that is located approximately 27 meters (90 ft) upstream (along the river centerline) of the proposed I-84 Bridge No. 01224. This crossing is one of six (6) waterway crossings over the river to be constructed under the State Project No. 151-273, improvements to Interstate 84 in Waterbury from Washington Avenue east to Pierpont Road. The subject 4.3-kilometer (2.7 mile) long highway project has been designed by Ammann & Whitney (formerly Berger, Lehman Associates, P.C. – BLA).

The new pedestrian bridge is necessary due to the realignment and widening of the Interstate 84 that requires the construction of the proposed Bridge No. 01224. As the upstream end of the proposed I-84 bridge falls where an existing pedestrian crossing is located, a new pedestrian bridge will be constructed 28 meters (92 ft) upstream of its present location.

The proposed superstructure will be a prefabricated, steel truss bridge founded on cast-in-place concrete abutments supported by spread footings. It will have a clear span length of 20.6 meters (68 ft; measured between the abutment faces) with an inside lane width of 3 meters (10 ft) and overall width of approximately 3.5 meters (11.5 ft). The crossing will be a part of a pedestrian walkway that leads to the downstream side of the I-84 Bridge to Hamilton Park.

This report finds that the proposed bridge will experience the greatest potential scour during the flow condition at which the bridge begins to overtop, which is 19-year discharge. The footing of the proposed structure will be placed such that its bottom will not be exposed to the maximum calculated scour.

Table 1. NBIS Ratings and Scour Related Design Information

Recommended NBIS Item 113 Rating	8
Recommended NBIS Item 71 Rating	7
Recommended NBIS Item 61 Rating	8
Scour Risk Designation	Low Risk
Depth of Potential Scour (Controlling Event: 19-year, Overtopping)	1.29 m (Abutment #1 – West); 2.34 m (Abutment #2 – East)
Foundation Type	Spread footings
Recommendations	Bottom of Footing Placed Below Predicted Scour; Riprap Bank Protection

Reference Reports

The following reports, prepared under separate covers for the project, should be referenced for more detailed information pertinent to the hydrology and hydraulics for the subject reach of the Mad River and the hydraulic design of the pedestrian bridge crossing.

- *Overview Report for Hydraulic Design, CT DEP Flood Management Certification & FEMA Conditional Letter Of Map Revision (CLOMR), Mad River & Beaver Pond Brook, Waterbury, Connecticut* prepared by ConnDOT, July 2006.
- *Hydrologic Report, Mad River* prepared by BLA, September 1999
- *Hydraulic Analysis for Design Report, Mad River* prepared by ConnDOT, revised April 2014.
- *Final River Relocation Report, Mad River & Beaver Pond Brook* prepared by BLA, January 2004 and revised by ConnDOT, April 2006.
- *Mad River Floodplain/Floodway Analysis Report for FEMA CLOMR & CTDEP Flood Management Certification* prepared by ConnDOT, revised April 2014.

Project Overview

The information presented in this report are mostly derived from the hydraulic analyses performed using the DOT "Design" discharges as presented in the *Hydraulic Analysis for Design Report, Mad River* prepared by ConnDOT, revised April 2014. For complete hydrologic information refer to *Hydrologic Report, Mad River* prepared by BLA (Ammann & Whitney), September 1999. The summarized hydrologic information is shown in the table below.

Table 2. Hydrologic Information

Watershed Area:	62.26 km^2 (24.04 mi^2)- Large Structure
Discharges:	19-Yr: 90.66 cms (3,200 cfs) ← *Overtopping*
	50-Yr: 137.34 cms (4,850 cfs) ← *Highest Flow Velocity*
	100-Yr: 176.98 cms (6,250 cfs)
	500-Yr: 269.01 cms (9,500 cfs)

See the Overview Report referenced above for an overview of the project, the existing and the proposed project conditions.

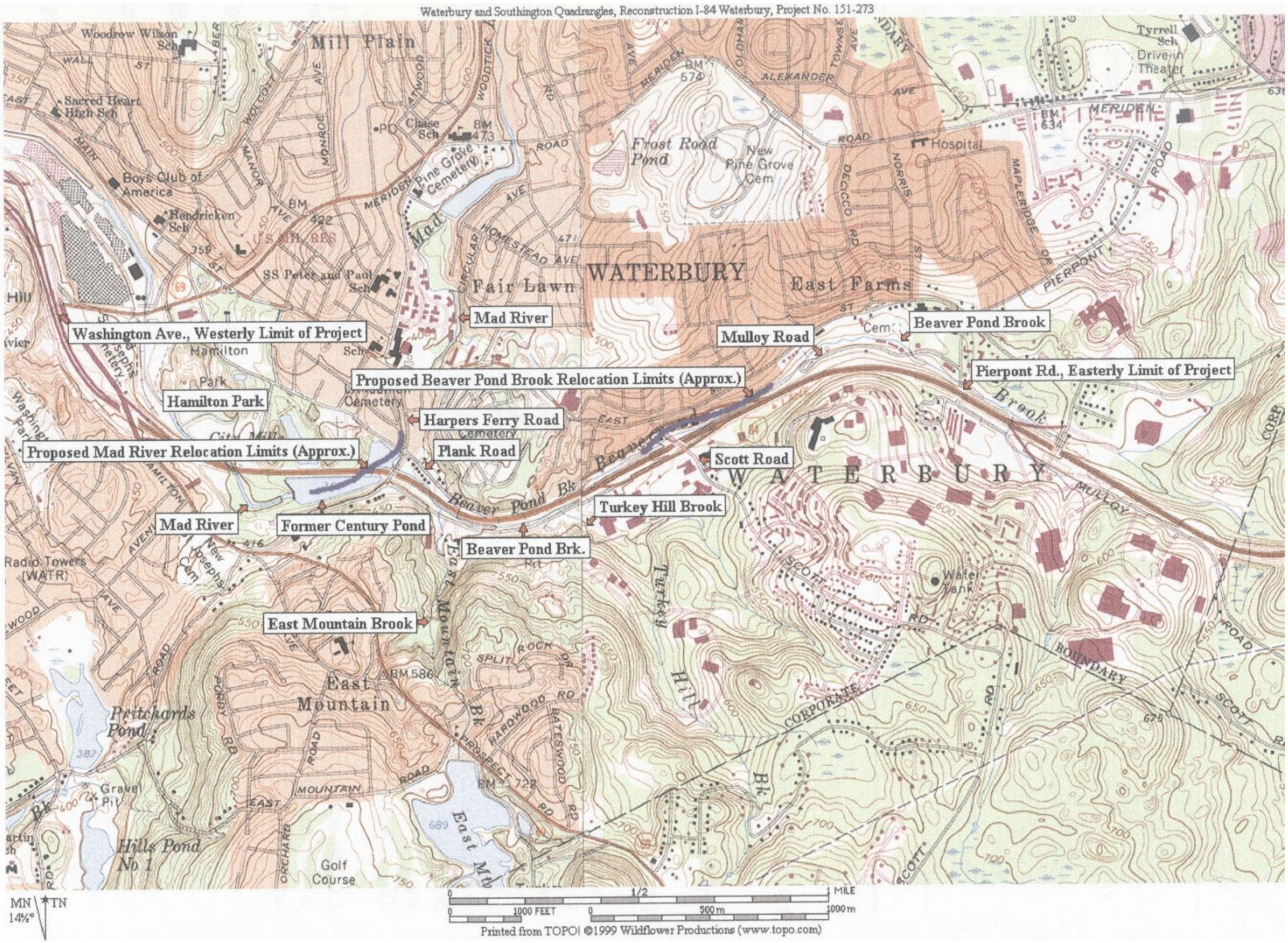


FIGURE 1 - PROJECT LOCATION PLAN

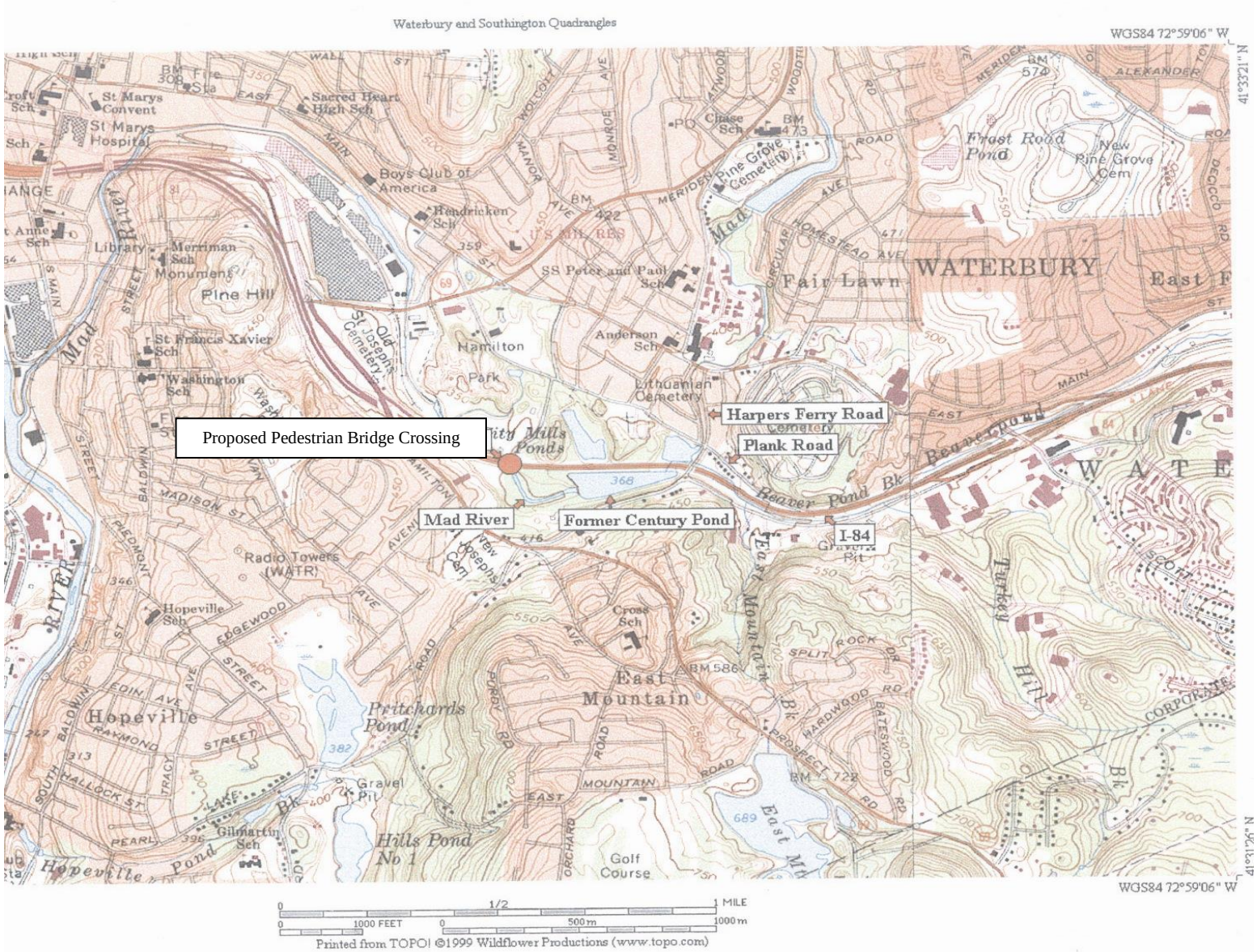
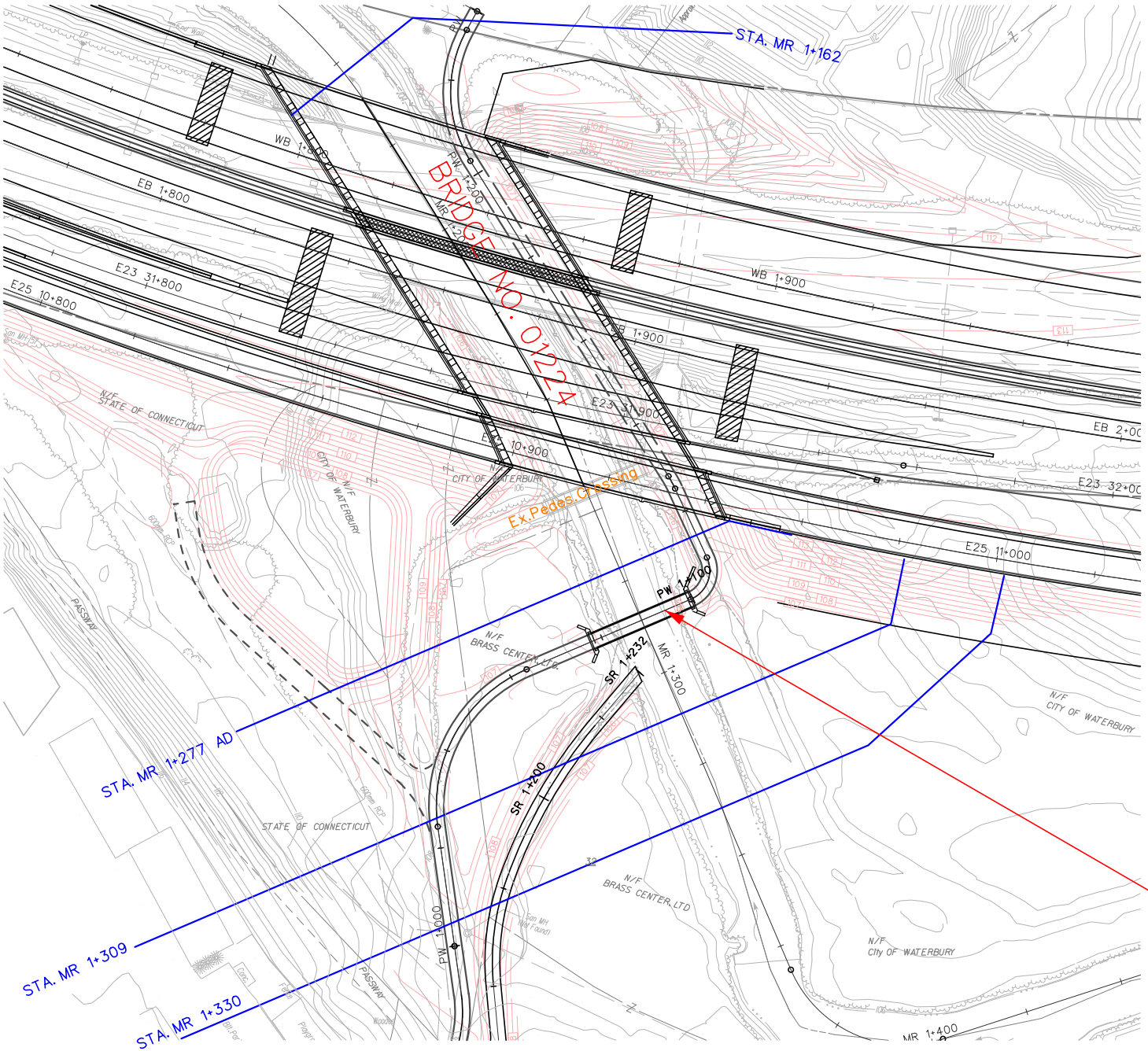


FIGURE 2 - STRUCTURE LOCATION PLAN



PROPOSED
PEDESTRIAN BRIDGE
OVER MAD RIVER

CROSS SECTION LOCATION PLAN

I-84 Waterbury
Project No. 151-273
(In State Plane Coordinate System)

Pedestrian Bridge

FIGURE 3 - CROSS SECTION LOCATION PLAN (VICINITY OF BRIDGE)

Report Background

This scour report with the accompanying final hydraulic report have been prepared as part of the final design for a pedestrian bridge crossing over the Mad River, that is located approximately 27 meters upstream (along the river centerline) of the proposed I-84 Bridge No. 01224. Due to the new I-84 bridge which is proposed to accommodate realignment and widening of the Interstate, the new pedestrian bridge will be constructed 28 meters (92 ft) upstream of its present location.

Scour depths have been estimated following procedures set forth by the Federal Highway Administration in Hydraulic Engineering Circular No. 18 (HEC-18), *Estimating Scour at Bridges*, May 2001. As recommended on page 9.B-2 of the *2000 ConnDOT Drainage Manual*, the following Amended Local Abutment Scour Equation was utilized:

$$Y_s/Y_a = [2.27\ K_1\ K_2\ (L'/Y_a)^{0.43}\ Fr^{0.61}] + 0.05 \qquad \text{(ConnDOT)}$$

This equation predicts scour depths for the 50th percentile as compared to the more conservative HEC-18 version of Froehlich's equation (equation 7.1, page 7.8), which would have encompassed 98% of the laboratory produced scour holes from the original study. The HEC-18 version of Froehlich's equation is as follows:

$$Y_s/Y_a = [2.27\ K_1\ K_2\ (L'/Y_a)^{0.43}\ Fr^{0.61}] + 1 \qquad \text{(HEC-18)}$$

A comparison of the two local abutment equations shows that ConnDOT's version will predict scour depths $0.95Y_a$ less than proposed by HEC-18. Y_a is the average depth of floodplain flow at the upstream approach cross section.

When overtopping condition exist or the water surface rises above the low chord, the hydraulic condition through the bridge changes, and can potentially increase the scour depth. Therefore, in addition to the typical contraction and local abutment scour assessment, a different scour component that can be generated by the pressure flow condition was also investigated. Due to limited studies on pressure flow scour, as stated in HEC-18, the equations mainly developed for pier scour analysis were utilized. As these equations pertain to flow-depth differential caused by the superstructure of a bridge, and not associated with the geometry of a pier, the usage in this case is deemed adequate.

The discharges used in this investigation have been approved by ConnDOT and are presented in the September 1999 *Hydrologic Report, Mad River, Waterbury, Connecticut* prepared by BLA. The discharges reported in the original 1979 and currently effective 2013 Waterbury Flood Insurance Study are 25-30% lower than those approved by ConnDOT.

The hydraulic analysis completed for this investigation utilized HEC-RAS version 4.1.0 assuming mixed flow conditions. A CD containing the HEC-RAS data files is included in the referenced *Hydraulic Analysis for Design Report, Mad River*.

Proposed Bridge

The superstructure of the proposed pedestrian bridge will be a prefabricated, steel truss structure founded on cast-in-place concrete abutments supported by spread footings. It will have a clear span length of 20.6 meters (67.6 feet, measured between the abutment faces) with an inside lane width of 3 meters (10 feet) and overall width of approximately 3.5 meters (11.5 ft). The crossing will be a part of the pedestrian walkway that will follow the easterly bank of the Mad River under the new I-84 Bridge No. 01224 to Hamilton Park. The existing walkway currently crosses under I-84 via the existing 3-m (10-ft) wide concrete box tunnel. This tunnel will be abandoned under this project.

Similar to the existing pedestrian bridge, the elevation of the new bridge deck will be relatively low to minimize both the need for high approach embankments and fill in the floodplain. The bridge will convey the 10-year flow with approximately 0.15 meter (0.5 ft) of underclearance. According to the hydraulic analysis, the overtopping flood will have an estimated recurrence interval of 19 years. The 100-year flood elevation will be approximately one meter (3 ft) above the bridge approaches.

As the new pedestrian bridge will be constructed where no structure currently exists, it signifies placing more physical constriction to the flow at this location. Nonetheless, the hydraulic analysis indicates that the resulting water surface elevations will be actually lower than the existing condition. For the 100-year discharge it will be lowered by approximately 0.11 m (0.36 ft) at the upstream and 0.22 m (0.72 ft) at the downstream faces of the bridge, and by 0.28 meter (0.92 ft) at the further downstream Section 1227. This is because of the differing downstream conditions. Downstream of new pedestrian bridge, the new westerly I-84 Bridge No. 01224 is proposed in close proximity such that its upstream face will be placed where the existing pedestrian bridge is located. The proposed I-84 bridge will present less constriction than the existing pedestrian bridge such that it generates a lower backwater toward the location of the new pedestrian bridge. Moreover, the existing pedestrian bridge is affected by the backwater from the existing I-84 structure which is hydraulically inferior compared to the proposed I-84 bridge due to the constriction caused by its piers. This causes greater rise over the existing pedestrian bridge than the similarly configured proposed bridge. This is evident in the results of the analysis which shows approximately 63 % of the 100-year flow going over the existing bridge, whereas the weir flow will be approximately 44 % over the proposed bridge.

With the more flow conveyed by the bridge opening, the flow velocity through the opening will be increased in the proposed condition. For the 100-year discharge, the proposed velocity will be 2.39 m/s (7.8 ft/s), which is 0.98 m/s (3.2 ft/s) higher than through the existing bridge. Among the studied discharges, the 50-year velocity was highest at 2.5 m/s (8.2 ft/s).

In order to minimize the bank erosion, the riprap will be placed around its abutments (see Appendix A for the location and the detail of the riprap protection). The required size of this riprap was evaluated based on Hydraulic Engineering Circular No. 11 (HEC-11) methodology. These calculations indicate that Standard sized riprap will be adequate for not only the 100-year design, but also the 19- (overtopping), 50- and 500-year flow conditions (see Appendix C).

Scour Potential Assessment and Results

Scour computations were completed for the 19-Year (overtopping), 50- (highest velocity through the bridge opening), 100- (Design), and 500- (Check) frequency discharges. The computations for other lower frequency discharges were not performed as the degree of contraction, velocity and other flow variables were found relatively moderate compared to the conditions under the above-specified frequency discharges. The scour assessment was performed primarily for the area under the bridge to design substructure correspondingly.

The estimate of D_{50} was based on a soil sample of existing bed material taken in the vicinity of the proposed pedestrian bridge (see Figure 4).

Figure 4. Soil Sample (For estimating D_{50} for Scour Analysis)

Scour analysis Soil Sample #1, upstream of I-84 Structure No. 01224, westerly riverbank, looking downstream, 12/7/00

Long-term channel scour was assumed to be 0.3 meter (oone foot) to account for potential streambed degradation due to relocating the Pedestrian Crossing to a "natural" cross section. Significant degradation is not anticipated because the existing channel bottom is well protected with boulders and cobbles and the proposed approach embankments will minimize the obstruction of relieving floodplain flows.

As described previously, local abutment scour depths were computed using the amended Froehlich's equation for Connecticut. Because of the significant overtopping conditions for the proposed structure, a separate hydraulic model had to be developed using reduced discharges representing only the portion that is conveyed through the bridge opening, in an effort to disregard overtopping flows in the scour estimates. This model provided the relevant flow variables upstream of the bridge such as effective length and depth of obstructed flow. The results of the model and how they are applied in the analysis are illustrated in the plots included with the computations in Appendix B.

Computed scour depths are tabulated as shown below:

Table 3. Summary of Computed Scour Depths

19-Year, Overtopping (controlling event for scour)	Scour Depths (m)				
	Long-Term	Contraction	Amended Abutment	Pressure Flow	Amended Total
Abutment 1(Westerly)	0.3	0.13	0.61	0.26	1.29
Abutment 2(Easterly)	0.3	0.13	1.66	0.26	2.34

50-Year (controlling event for channel bank protection design)	Scour Depths (m)				
	Long-Term	Contraction	Amended Abutment	Pressure Flow	Amended Total
Abutment 1(Westerly)	0.3	0.14	0.48	0.05	0.96
Abutment 2(Easterly)	0.3	0.14	1.58	0.05	2.06

100-Year	Scour Depths (m)				
	Long-Term	Contraction	Amended Abutment	Pressure Flow	Amended Total
Abutment 1(Westerly)	0.3	0.03	0.46	0	0.79
Abutment 2(Easterly)	0.3	0.03	1.49	0	1.83

500-Year	Scour Depths (m)				
	Long-Term	Contraction	Amended Abutment	Pressure Flow	Amended Total
Abutment 1(Westerly)	0.3	0	0.42	0	0.72
Abutment 2(Easterly)	0.3	0	1.05	0	1.35

The foundation of the bridge is designed such that the estimated scour resulting from the above flood events will not completely expose the footings.

Design Review for Scour and Conclusions

Footing
For spread footings on soil, page 2.3 of HEC-18 recommends:

- Placing the top of footing below the sum of long-term degradation and contraction scour
- Placing the bottom of footing below the total scour depth

The top of the footing has been located in accordance with this guideline for all the investigated flow conditions. For both abutments, the top of the footing will be set at elevation 103.0 M. The thickness of the footing will be one (1) meter (vertically).

"Superflood"
Page 2.4 of HEC-18 recommends that the foundation design should be checked for scour conditions resulting from a "Superflood". The design "should have a minimum factor of safety of 1.0 (ultimate load) under the superflood conditions." For this bridge the 500 year flood was assumed to be the "Superflood". The scour computations indicate that the 500 year flood will not expose the bottom of either footing which satisfies HEC-18 recommendations. In fact, during the 500-year discharge, approximately 67% of the flow will flow over the bridge rather than through the bridge opening.

Revetment Design
Although the foundations have been designed to the computed total scour depth which is based on the fine particle size of the existing streambed material, the design also incorporates riprap slope protection to further protect the bridge. As indicated earlier, the design of the protection was based on the method described in the HEC-11. The results are included in Appendix C.

The hydraulic analysis indicates that the flow velocity through the bridge opening is highest (among the studied events) for the 50-year discharge. Since other flow variables necessary in the HEC-11 calculations, such as flow area and width of flow, remain consistent for all the studied discharges (flow area = bridge opening area; width of flow = bridge opening width), the analysis for the worst case (highest velocity) only is deemed sufficient. The result of the analysis indicates that the proposed Standard Riprap is adequate.

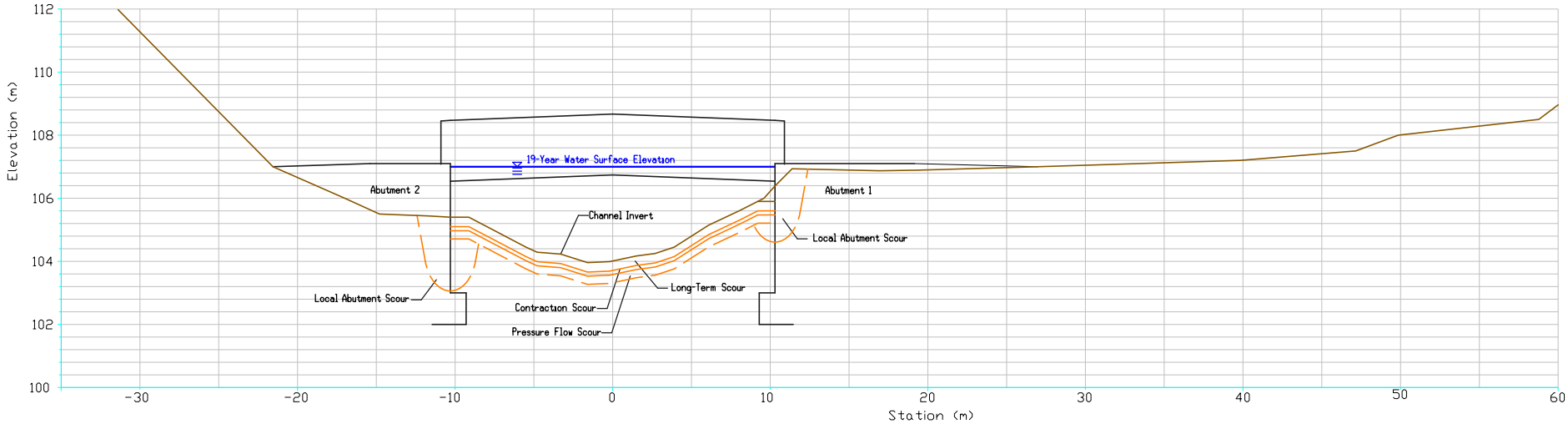
Beneath the Standard Riprap, a 150 mm-thick Granular Fill layer on geotextile will be provided to prevent loss of fines through the voids, as its requirement is demonstrated in the computations. As indicated previously, the scour analysis was performed mainly for the area under the proposed bridge. In overtopping flow conditions, however, erosion may occur along the approach sections to the bridge or along the floodplains where the overflow will be constricted to pass around the superstructure. Therefore, the coverage of the riprap protection was not limited to the area under the bridge, but has been expanded around both ends of the bridge. The coverage and typical details of the riprap protection are shown in Appendix A.

The channel stability analysis for other locations of the Mad River within the subject project limits is included in the *Final River Relocation Report, Mad River & Beaver Pond Brook*.

Figure 5. Scour Depth Cross Sections

Sheet 1 (19- & 50-Year Discharges)

Proposed Pedestrian Bridge Crossing, Section Along The Upstream Face, I-84 Waterbury Project 151-273, Mad River



Proposed Pedestrian Bridge Crossing, Section Along The Upstream Face, I-84 Waterbury Project 151-273, Mad River

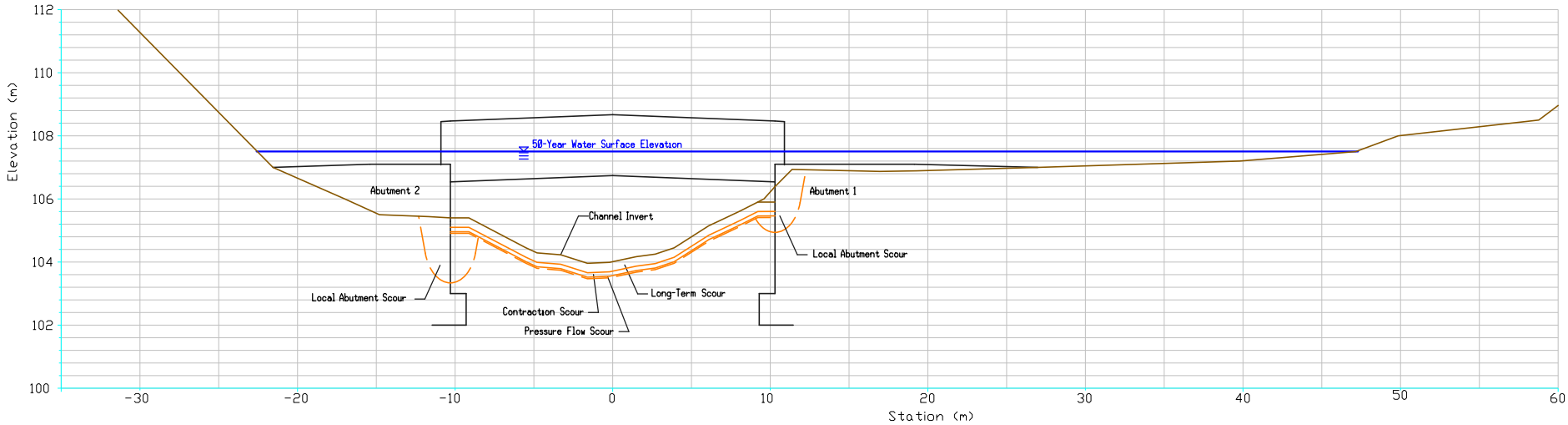
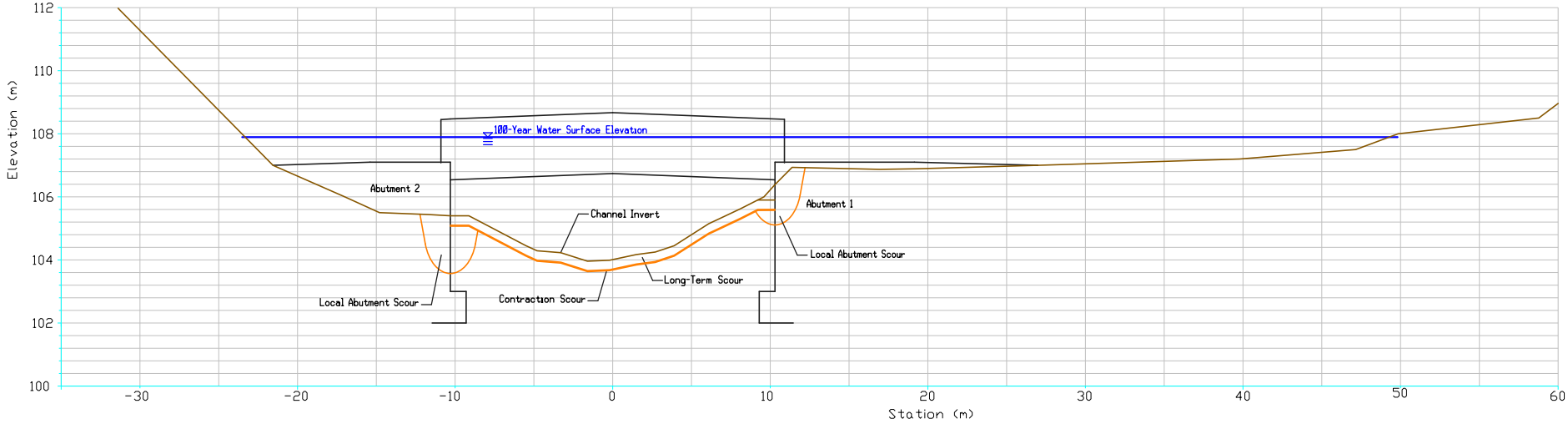


FIGURE 5 (1/2)

Figure 5. Scour Depth Cross Sections

Sheet 2 (100- & 500-Year Discharges)

Proposed Pedestrian Bridge Crossing, Section Along The Upstream Face, I-84 Waterbury Project 151-273, Mad River



Proposed Pedestrian Bridge Crossing, Section Along The Upstream Face, I-84 Waterbury Project 151-273, Mad River

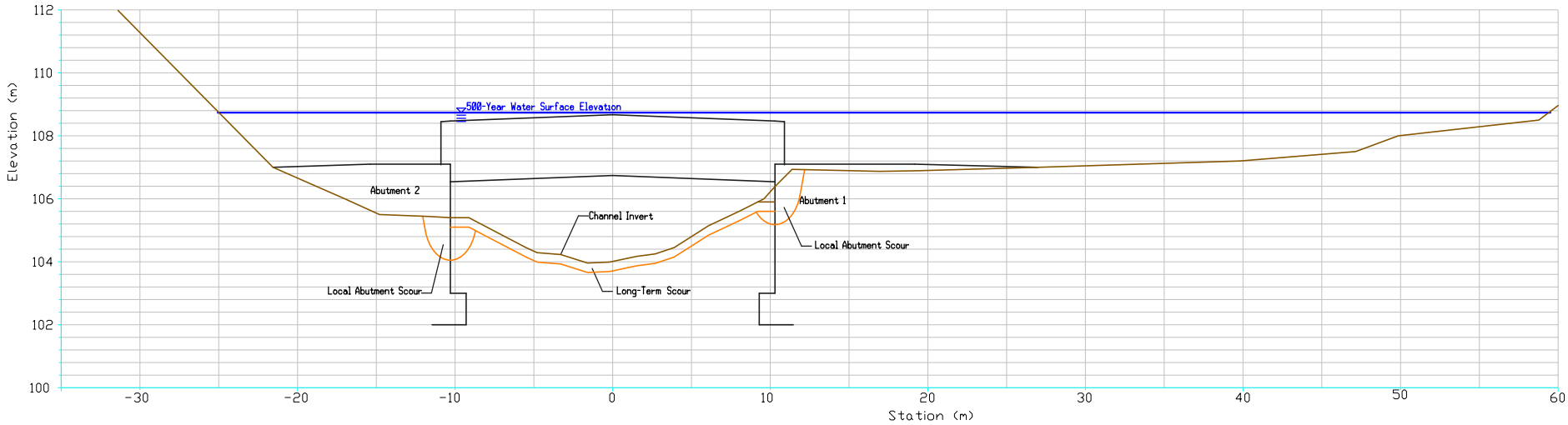
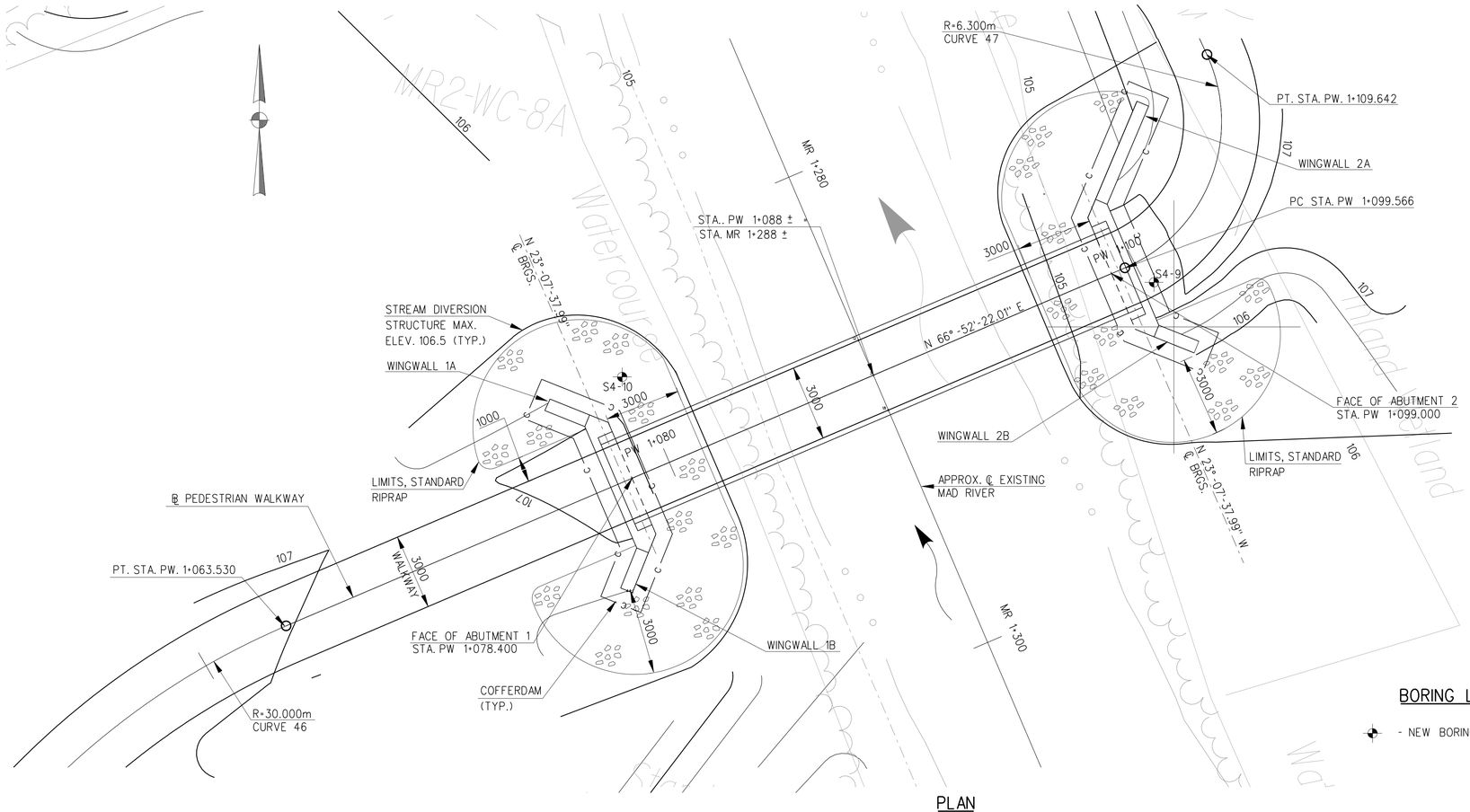


FIGURE 5 (2/2)

Appendix A: Structure Plans & Details

(Note: The plans and details included in this report are intended for information purposes only. If there are any discrepancies to the actual construction or "as-built" plans, the information reflected on the construction or "as-built" plans shall be construed more accurate.)



PLAN
SCALE 1:100

PEDESTRIAN WALKWAY-CURVE 46		
P.C.	STA.	PW 1+024.350
	N	230801.452
	E	282467.089
C.C.	N	230805.605
	E	282496.800
P.T.	STA.	PW 1+063.530
	N	230833.194
	E	282485.017
△		74°-49'-44.97"
R		30.000 m
T		22.949 m
L		39.181 m

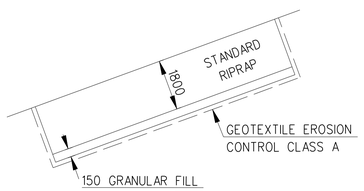
PEDESTRIAN WALKWAY-CURVE 47		
P.C.	STA.	PW 1+099.566
	N	230847.348
	E	282518.156
C.C.	N	230853.141
	E	282515.682
P.T.	STA.	PW 1+109.642
	N	230855.781
	E	282521.402
△		91°-38'-24.26" L
R		6.300 m
T		6.483 m
L		10.076 m

CURVE DATA

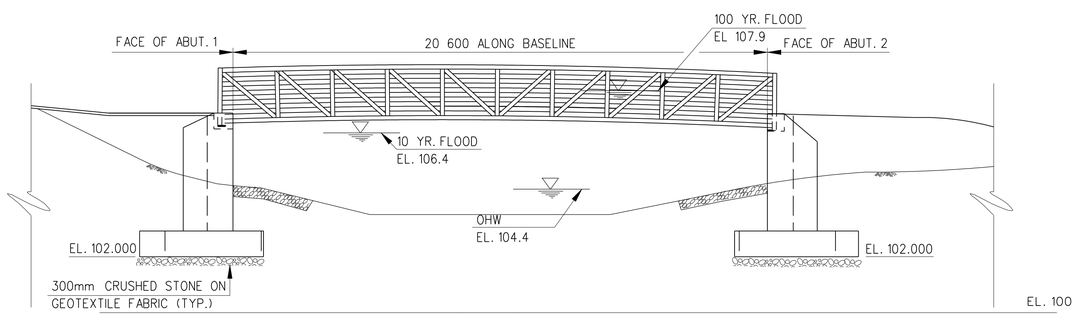
BORING LEGEND

- NEW BORING (2002)

BRIDGE/CULVERT NO.	Pedestrain Bridge
Drainage Area, km2	62.3
Design Frequency, year	100
Design Discharge, cms	176.98
Average Daily Flow Elevation, M	104.4 (observed)
Upstream Design Water Surface Elevation, M	107.89
Downstream Design Water Surface Elevation, M	107.79
Maximum Scour Elevation, M	102.95
Frequency (year)	19 (overtopping)
Discharge (cms)	90.66
Worst case scour sub-strucutre unit	Abutment #2 (East; North End))



RIPRAP TYPICAL DETAIL
N.T.S.



ELEVATION
SCALE 1:100

WATER HANDLING NOTES:

1. THE TOP OF THE STREAM DIVERSION STRUCTURE AND COFFERDAMS SHALL BE INSTALLED TO AN ELEVATION NOT TO EXCEED 106.5m ✳ AND IN THE GENERAL LOCATION DEPICTED ON THE PLANS. ABOVE THIS ELEVATION THE FLOW OF THE RIVER SHALL BE CAPABLE OF OVERTOPPING THE STREAM DIVERSION STRUCTURE. THE CONTRACTOR IS ADVISED THAT SUCH OVERTOPPING WILL OCCUR FOR ANY EVENT WITH A DISCHARGE GREATER THAN A STORM WITH APPROXIMATELY A TWO YEAR FREQUENCY OF OCCURRENCE. THE CONTRACTOR SHALL EITHER ACCEPT THE RISK FOR DAMAGE TO UNCOMPLETED WORK DUE TO SUCH AN OCCURANCE OR OBTAIN AT HIS OWN EXPENSE INSURANCE PROTECTING AGAINST SAME.
2. ANY ALTERNATIVE CONSTRUCTION PROCEDURE PROPOSED BY THE CONTRACTOR MUST PROVIDE AT ALL TIMES A HYDRAULIC CONVEYANCE CAPACITY EQUAL TO OR GREATER THAN THAT PROVIDED BY THE STAGING SHOWN ON THE PLANS.
3. PAYMENT FOR STREAM DIVERSION STRUCTURES AND DEWATERING FOR RIPRAP INSTALLATION ARE INCLUDED IN THE ITEM "HANDLING WATER."
4. STAGING OF CONSTRUCTION IN THE WATERWAY MUST BE COORDINATED WITH CONSTRUCTION FOR STRUCTURE NO. 151-273-01224. SEE PERMIT APPLICATION.

✳ TOP OF COFFERDAM MAY EXCEED THIS ELEVATION WHERE NECESSARY TO RETAIN EXISTING GROUND.

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

DESIGNER: L. MARQUEZ
DRAFTER: M. MOSLEY
CHECKED BY: B. YIN
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\Ped_Bridge\FD\0273f012001.brg
PLOTTED 5/21/2014

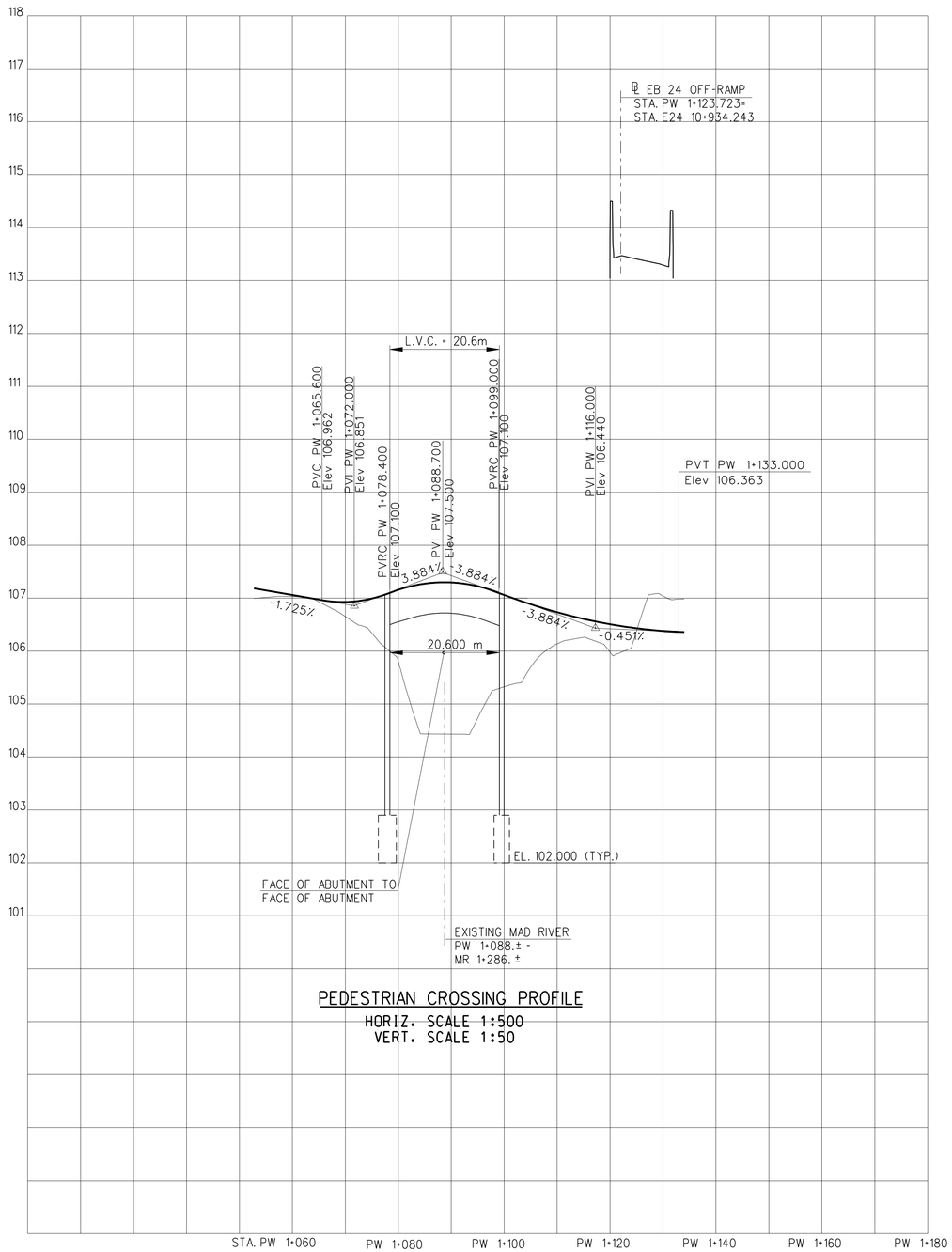
AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

PROJECT TITLE:
RECONSTRUCTION OF I-84
WATERBURY
PEDESTRIAN WALKWAY
OVER MAD RIVER

TOWN: WATERBURY

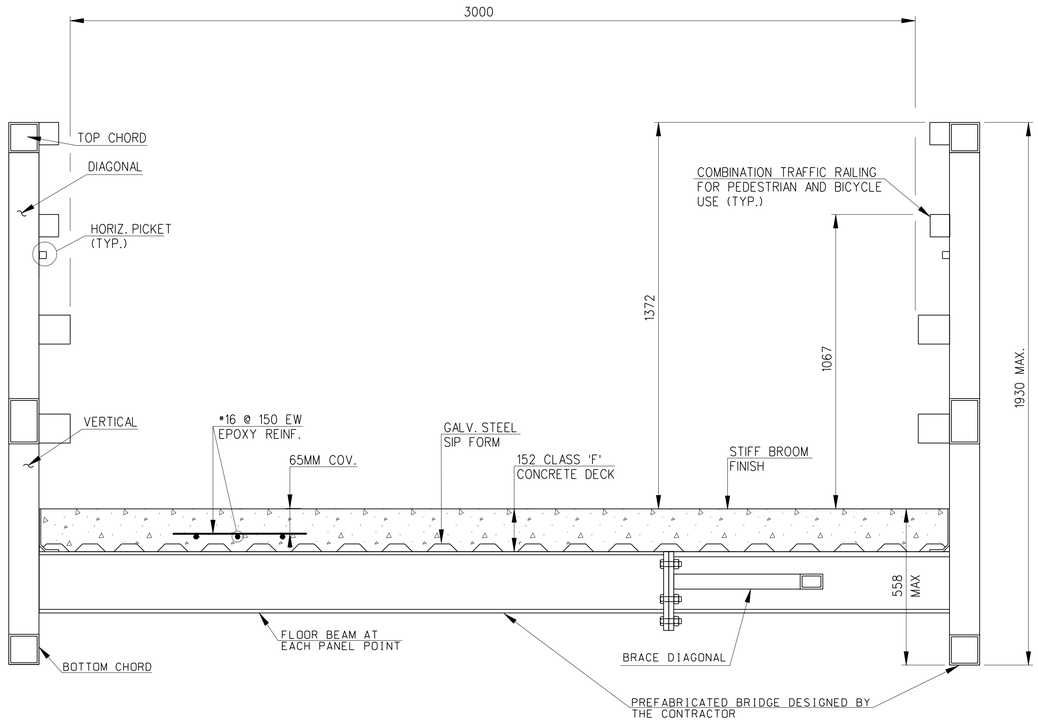
DRAWING TITLE: GENERAL PLAN AND ELEVATION

PROJECT NO.: 151-273
DRAWING NO.: S1
SHEET NO.: 05.09.001



PEDESTRIAN CROSSING PROFILE

HORIZ. SCALE 1:500
VERT. SCALE 1:50



TYPICAL BRIDGE SECTION

SCALE 1:50

NOTES:

1. THE BRIDGE SHALL HAVE A VERTICAL CAMBER DIMENSION AT MIDSPAN EQUAL TO THE FULL DEAD LOAD DEFLECTION, ANY VERTICAL CURVE ORDINATE PLUS 1% OF THE LENGTH OF THE BRIDGE.

2. CLASS "F" CONCRETE FOR STRUCTURE DECK AND EPOXY COATED DEFORMED BARS ARE INCLUDED IN THE PAYMENT FOR PEDESTRAIN BRIDGE ITEM.

REV.	DATE	DESCRIPTION	SHEET. NO.
		REVISIONS	

SCALE AS NOTED

DESIGNER: L. MARQUEZ
DRAFTER: M. MOSLEY
CHECKED BY: B. YIN
DATE CHECKED: 12/2013

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

CADD ...\Ped_Bridge\FD\0273f012004.brg
PLOTTED 4/7/2014

AMMANN & WHITNEY
2500 WESTCHESTER AVENUE
3RD FLOOR
HARRISON, NY

PROJECT TITLE:
RECONSTRUCTION OF I-84
WATERBURY
PEDESTRIAN WALKWAY
OVER MAD RIVER

TOWN: WATERBURY

DRAWING TITLE:
PROFILES & TYPICAL BRIDGE SECTION

PROJECT NO.: 151-273
DRAWING NO.: S3
SHEET NO.: 05.09.003

Appendix B: Scour Computations

Based on DOT Design Discharges

- Summary Sheet
- 19-YR (Overtopping) Contraction Scour
- 19-YR (Overtopping) Abutment Scour
- 19-YR (Overtopping) Pressure Flow Scour
- 50-YR (Highest Flow Velocity) Contraction Scour
- 50-YR (Highest Flow Velocity) Abutment Scour
- 50-YR (Highest Flow Velocity Pressure Flow Scour
- 100-YR Contraction Scour
- 100-YR Abutment Scour
- 100-YR Pressure Flow Scour
- 500-YR Contraction Scour
- 500-YR Abutment Scour
- 500-YR Pressure Flow Scour
- Soil Sample Analysis (Sample #1, bed material)

Final Design

Pedestrian Footbridge Over the Mad River

Computed Scour Depths using Froehlich's Abutment Scour Equation

For The Area Under The Bridge Only

July 2006 - Revised October 2013

Abutment #1- Westerly Abutment or Right Abutment Looking Upstream

	Flood Recurrence	Ave. Flow Depth Obstructed	Scour Depth (m)					
			Long-Term	Contraction	Abutment Equation	Amended Abutment	Pressure Flow	Amended Total
Control event->	**$Q_{19\ (Overtoppping)}$**	**0.18**	**0.3**	**0.13**	**Froehlich**	**0.61**	**0.26**	**1.29**
	Q_{50}	0.29	0.3	0.14	Froehlich	0.48	0.05	0.96
	Q_{100}	0.15	0.3	0.03	Froehlich	0.46	0.00	0.79
	Q_{500}	0.16	0.3	0.00	Froehlich	0.42	0.00	0.72

Abutment #2- Easterly Abutment or Left Abutment Looking Upstream

	Flood Recurrence	Ave. Flow Depth Obstructed	Scour Depth (m)					
			Long-Term	Contraction	Abutment Equation	Amended Abutment	Pressure Flow	Amended Total
Control event->	**$Q_{19\ (Overtoppping)}$**	**0.89**	**0.3**	**0.13**	**Froehlich**	**1.66**	**0.26**	**2.34**
	Q_{50}	1.00	0.3	0.14	Froehlich	1.58	0.05	2.06
	Q_{100}	0.96	0.3	0.03	Froehlich	1.49	0.00	1.83
	Q_{500}	0.88	0.3	0.00	Froehlich	1.05	0.00	1.35

Comparison of Footing Elevations to Computed Scour Depths

Abutment No.	Depth of Footing (m)	Elevation (m)		Assumed Ground Elevation at Base of Abutment	Elevation of Scour at Abutment (m)			
					Control Event (19-yr,ovt)		500-Year Discharge	
		Top of Footing	Bottom of Footing		Long-Term + Contraction	Total	Long-Term + Contraction	Total
1 (U/S)	1.0	103.0	102.0	105.90	105.47	104.61	105.60	105.18
2	1.0	103.0	102.0	105.40	104.97	103.06	105.10	104.05

Abutment No. 1

-Top of footing below the sum of long-term channel degradation and contraction scour depths for the scour critical discharge- Design OK

-Computed total scour depth for the "overtopping" discharge is above the bottom of the footing

-Computed total scour depth for the 50-year discharge is above the bottom of the footing

-Computed total scour depth for the 100-year discharge is above the bottom of the footing

-Computed total scour depth for the 500-year discharge is above the bottom of the footing

Abutment No. 2

-Top of footing below the sum of long-term channel degradation and contraction scour depths for the scour critical discharge- Design OK

-Computed total scour depth for the "overtopping" discharge is above the bottom of the footing

-Computed total scour depth for the 50-year discharge is above the bottom of the footing

-Computed total scour depth for the 100-year discharge is above the bottom of the footing

-Computed total scour depth for the 500 year discharge is above the bottom of the footing

PROJECT NO. 151-273 **BRIDGE NO.** Pedestrian Crossing **UNIT:** Metric

Ref. HEC-18., May 2001 (4th ed.)

(October 2013 Note: These equation are still valid in HEC-18, 5th ed.)

SUMMARY

Contraction Scour		Type:	**LIVE-BED**	Depth:	**0.13** m	Event:	**19-YR(OVT)**
Local	**East Abut. #2**	**LEFT**	Eq.: Froehlich	Depth:	**1.66** m	Event:	**19-YR(OVT)**
Abutment	**West Abut. #1**	**RIGHT**	Eq.: Froehlich	Depth:	**0.61** m	Event:	**19-YR(OVT)**

CONTRACTION SCOUR

$Vc = Ku\ y^{1/6}\ D^{1/3}$ .....Eq. 5.1

= **2.05** ***m/s*** Critacal velocity above which bed material of size D and smaller will be transported

Ku = 6.19 m (6.19 in SI units; 11.17 in English units)

y = 2.27 m Average depth of flow upstream of the bridge

D = 0.024 m Particle size for Vc *, m* (use D_{50})

V = **2.18** ***m/s*** The mean velocity of the flow in the main channel or overbank area upstream of the brige opening

Vc < V ***Thus, LIVE-BED CONTRACTION SCOUR***

Live-Bed Contraction Scour ==========

$Y_2/Y_1 = (Q_2/Q_1)^{6/7}\ (W_1/W_2)^{k_1}$ = **0.90** .....Eq. 5.2

$Y_s = Y_2 - Y_o$ **m** .....Eq. 5.3

= **0.13 m** Average contraction scour depth

Y_1 = 2.27 m Average depth in the upstream main channel

Y_2 = 2.04 m Average depth in the contracted section

Y_o = 1.91 m Existing depth in the contracted section before scour

Q_1 = 82.89 m3/s Flow in the upstream channel transporting sediment

Q_2 = 85.93 m3/s Flow in the contracted channel

W_1 = 16.34 m Bottom width of the upstream main channel that is transporting bed material

W_2 = 20.60 m Bottom width of the main channel in the contracted section less pier width

k_1 = 0.59 Exponent determined below (V^*/ω = 0.40)

V^* = 0.2496 $=(T_o/\rho)^{1/2}$ or $(gY1\ S1)^{1/2}$, shear velocity in the upstream section , m/s

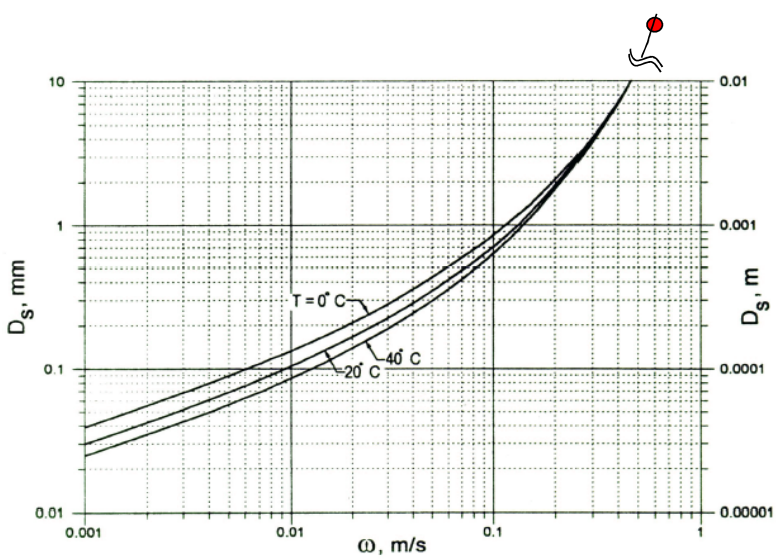
ω = 0.63 m/s Fall velocity of bed material based on the D_{50} (Figure 5.8)

g = 9.81 m/s^2 Acceleration of gravity

S1 = 0.002803 m/m Slope of energy gradeline of main channel

T_o = 60.41 Pa (N/m^2) Shear stess on the bed

ρ = 1000 kg/m^3 Density of water



V^*/ω	k1	*Mode of Bed Material Transport*
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

Figure 5.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Clear-Water Contraction Scour ==========

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2}\right]^{3/7}$$ .....Eq. 5.4

$$y_s = y_2 - y_o$$ **m** .....Eq. 5.5

=	**N/A**	**m**	Average contraction scour depth **LIVE-BED controls. Ignore this procedure**
y_2 =	1.91	m	Average equilibrium depth in the contracted section after contraction scour
y_o =	1.91	m	Average existing depth in the contracted section
Q =	85.92	m3/s	Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W
W =	20.60	m	Bottom width of the contracted section less pier widths
K_u =	0.0250		(0.025 in SI units; 0.0077 in English units)
D_m =	0.0300	m	Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in th contacted setion
D_{50} =	0.0240	m	Median diameter of bed material

Because D_{50} is not the largest particle in the bed material, the scoured section can be slightly armored. Therefore, the D_m is assumed to be 1.25 D_{50}. For stratified bed material the depth of scour can be determined by using the clear-water scour equation sequentially with successive D_m of the bed material layers.

Data Source

Eq. 5.1			From:	RS
y =	2.27	m	D	1309
V =	2.18	m	D	1288.5 BR U

Eq. 5.2 & 5.3				
Y1 =	2.27	m	D	1309
Yo =	1.91	m	D	1288.5 BR U
Q1 =	82.89	m3/s	D	1309
Q2 =	85.93	m3/s	D	1288.5 BR U
W1 =	16.34	m	D	1309
or	(n/a)	m (manual)		
W2 =	20.6	m	D	1288.5 BR U
or	(n/a)	m (manual)		
S1 =	0.002803	m/m	C	1309
To =	60.41	Pa (N/m^2)	C	1309
P2 =	0	m (pier width)		

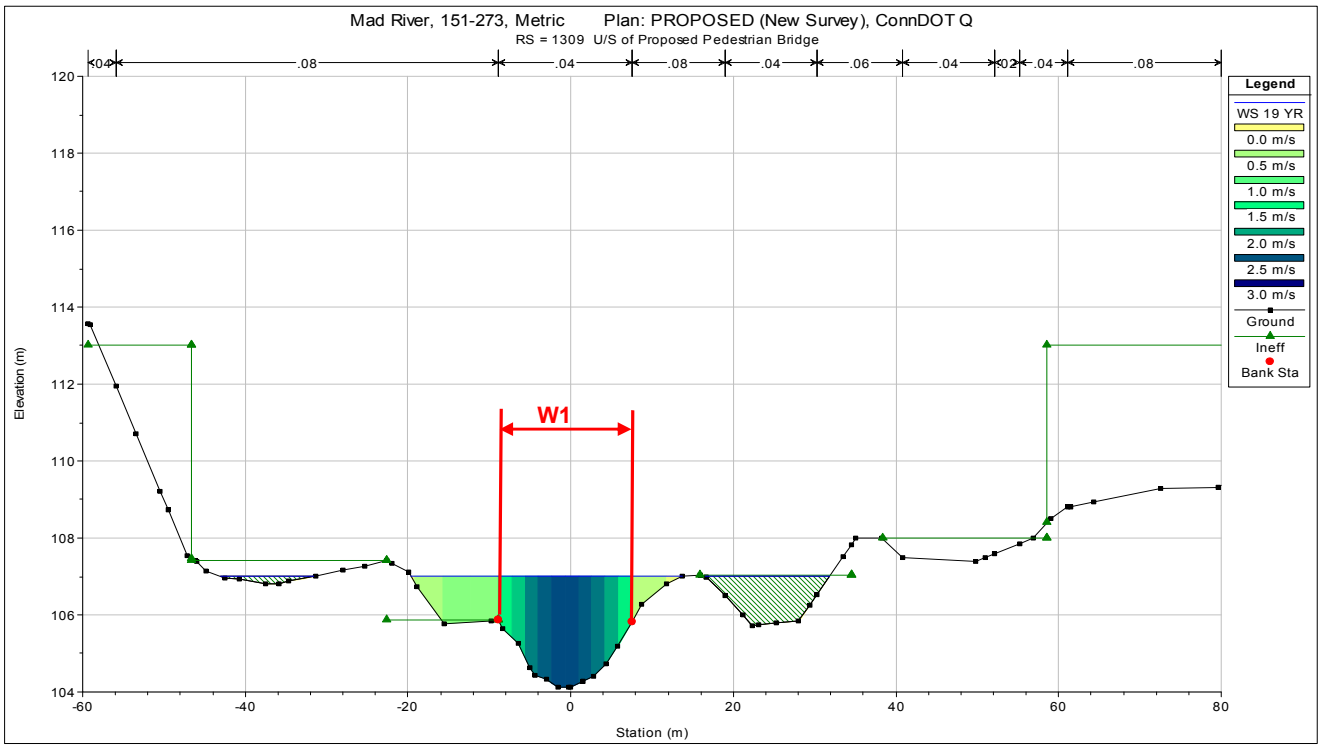
Eq. 5.4 & 5.5				
Q =	85.92	m3/s	C	1288.5
W =	20.6	m	C	1288.5
yo =	1.91	m	C	1288.5

Legends:

T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

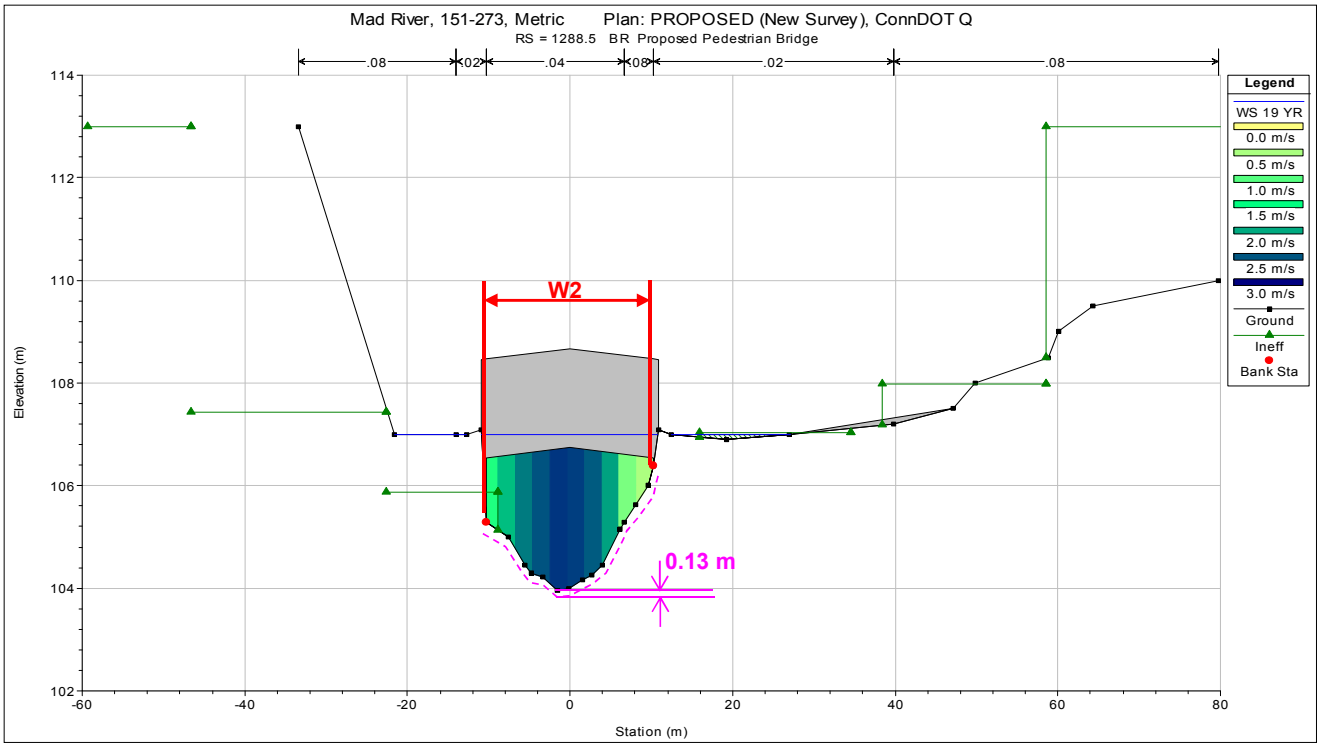
Cross Sections used for Contraction Scour Computations

UPSTREAM SECTION 1309



*This drawing is intended to provide a basic, rough visualization of the scour depth. See Figure 5 for a more accurate depiction.

CONTRACTED SECTION 1288.5 BR U



UPSTREAM CHANNEL SECTION

River Station 1309 Event: 19-YR(OVT)

HEC-RAS CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 19 YR

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	107.24	Element				
Vel Head (m)	0.23	Wt. n-Val.	0.08	0.04	0.08	
W.S. Elev (m)	107	Reach Len. (m)	19	19	19	
Crit W.S. (m)	106.24	Flow Area (m2)	10.49	37.04	2.73	
E.G. Slope (m/m)	0.002803	Area (m2)	11.66	37.04	15.4	64.1
Q Total (m3/s)	90.66	Flow (m3/s)	6.75	82.88	1.03	
Top Width (m)	60	Top Width (m)	22.28	16.34	21.39	
Vel Total (m/s)	1.8	Avg. Vel. (m/s)	0.64	2.24	0.38	
Max Chl Dpth (m)	2.88	Hydr. Depth (m)	0.97	2.27	0.44	1.07
Conv. Total (m3/s)	1712.5	Conv. (m3/s)	127.4	1565.6	19.5	
Length Wtd. (m)	19	Wetted Per. (m)	10.96	16.85	6.3	
Min Ch El (m)	104.12	Shear (N/m2)	26.32	60.41	11.9	
Alpha	1.42	Stream Power (N/m s)	5742.47	0	0	
Frctn Loss (m)		Cum Volume (1000 m3)	0.2	18.12	0.24	
C & E Loss (m)		Cum SA (1000 m2)	0.63	10.39	0.74	

	Flow dis.	*manual*
Left WS Sta.		-19.62
Left Convy Sta.	-15.73	
Left Main Channel	-8.84	
Right Main Channel	7.5	
Right Convy Sta.	13.15	13.35
Right WS Sta.		13.66

L' (left)	6.89	L (left)	10.78
L' (Right)	5.85	L (Right)	6.16

HEC-RAS FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	
LEFT		6.75	10.5			53.63
Main	16.34	82.89	37.03	2.27	36.82	1363.31
Right		2	17.94			6.68

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 19 YR

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-43.17	-39.75	0	0.18	3.31	0	0.05	0	1.5	0
2	LOB	-39.75	-36.32	0	0.53	3.43	0	0.15	0	4.23	0
3	LOB	-36.32	-32.9	0	0.42	3.43	0	0.12	0	3.36	0
4	LOB	-32.9	-29.47	0	0.04	1.34	0	0.03	0	0.72	0
5	LOB	-29.47	-26.05							0	0
6	LOB	-26.05	-22.62							0	0
7	LOB	-22.62	-19.18	0	0.04	0.47	0	0.08	0.11	2.1	0.24
8	LOB	-19.18	-15.73	1.11	2.36	3.59	1.23	0.68	0.47	18.03	8.5
9	LOB	-15.73	-12.29	2.91	4.13	3.45	3.21	1.2	0.7	32.9	23.15
10	LOB	-12.29	-8.84	2.73	3.97	3.45	3.01	1.15	0.69	31.68	21.74
11	Chan	-8.84	-7.21	3.59	2.3	1.71	3.96	1.41	1.56	37.01	57.7
12	Chan	-7.21	-5.57	5.34	2.94	1.74	5.89	1.8	1.82	46.49	84.39
13	Chan	-5.57	-3.94	8.91	3.98	1.71	9.83	2.43	2.24	63.77	142.89
14	Chan	-3.94	-2.3	10.66	4.35	1.64	11.75	2.66	2.45	72.79	178.16
15	Chan	-2.3	-0.67	11.92	4.65	1.64	13.15	2.85	2.56	77.91	199.52
16	Chan	-0.67	0.96	11.9	4.65	1.64	13.12	2.84	2.56	77.91	199.51
17	Chan	0.96	2.6	10.86	4.4	1.64	11.98	2.69	2.47	73.67	181.73
18	Chan	2.6	4.23	9.21	4.01	1.67	10.16	2.46	2.3	66.12	151.77
19	Chan	4.23	5.87	6.65	3.33	1.71	7.34	2.04	2	53.63	107.08
20	Chan	5.87	7.5	3.85	2.42	1.74	4.24	1.48	1.59	38.1	60.56
21	ROB	7.5	11.73	1.01	2.54	4.36	1.11	0.6	0.4	15.99	6.36
22	ROB	11.73	15.97	0.02	0.19	1.94	0.03	0.1	0.12	2.67	0.32
23	ROB	15.97	22.14	0	3.29	5.66	0	0.6	0	16	0
24	ROB	22.14	28.3	0	7.46	6.19	0	1.21	0	33.15	0
25	ROB	28.3	34.47	0	1.92	3.69	0	0.54	0	14.27	0
26	ROB	7.5	10.32	0.87	2	2.93	0.96	0.71	0.44		
27	ROB	10.32	13.15	0.1	0.54	2.85	0.11	0.19	0.19		
28	ROB	13.15	15.97	0	0	0.2	0	0.01	0.03		
29	ROB	15.97	18.61	0	0.02	0.58	0	0.03	0		
30	ROB	18.61	21.26	0	0.48	2.65	0	0.18	0		
31	ROB	21.26	23.9	0	0.88	2.64	0	0.33	0		
32	ROB	23.9	26.54	0	1.1	2.65	0	0.42	0		
33	ROB	26.54	29.18	0	0.64	2.63	0	0.25	0		
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CONTRACTED CHANNEL SECTION

River Station 1288.5 BR U

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 19 YR

E.G. Elev (m)	107.24	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.27	Wt. n-Val.				
W.S. Elev (m)	107	Reach Len. (m)	3.5	3.5	3.5	
Crit W.S. (m)	105.96	Flow Area (m2)	2.5	39.41	4.61	
E.G. Slope (m/m)		Area (m2)	0.01	39.41	0.82	40.24
Q Total (m3/s)	90.66	Flow (m3/s)	1.73	85.92	2.95	
Top Width (m)	23.53	Top Width (m)	8.89		14.64	
Vel Total (m/s)	1.95	Avg. Vel. (m/s)	0.69	2.18	0.64	
Max Chl Dpth (m)	3.04	Hydr. Depth (m)	0.28		1.29	1.71
Conv. Total (m3/s)		Conv. (m3/s)				
Length Wtd. (m)	3.5	Wetted Per. (m)	8.89	43.07	3.58	
Min Ch El (m)	103.96	Shear (N/m2)				
Alpha	1	Stream Power (N/m s)	3816.83	0	0	
Frctn Loss (m)		Cum Volume (1000 m3)	0.09	17.39	0.08	
C & E Loss (m)		Cum SA (1000 m2)	0.34	10.23	0.39	

		Flow dis.	*manual*
Left WS Sta.			-10.3
Left Flood Sta.			-10.3
Left Main Channel	-10.3		
Right Main Channel	10.3		
Right Flood Sta.			10.3
Right WS Sta.			10.3
L' (left)	0	L (left)	0
L' (Right)	0	L (Right)	0

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT					
Main	20.6	85.93	39.41	1.91	2.18
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 19 YR

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	Chan	-10.3	-8.84	2.6	1.96	4.18	3.02	1.34	1.33	0	0
2	Chan	-8.84	-6.71	6.39	3.4	4.29	7.44	1.6	1.88	0	0
3	Chan	-6.71	-4.59	10.3	4.54	4.31	11.98	2.13	2.27	0	0
4	Chan	-4.59	-2.46	13.09	5.22	4.27	15.24	2.45	2.51	0	0
5	Chan	-2.46	-0.33	15.54	5.78	4.26	18.08	2.72	2.69	0	0
6	Chan	-0.33	1.79	14.78	5.61	4.26	17.2	2.64	2.64	0	0
7	Chan	1.79	3.92	12.52	5.08	4.27	14.57	2.39	2.46	0	0
8	Chan	3.92	6.05	8.06	3.93	4.36	9.38	1.85	2.05	0	0
9	Chan	6.05	8.17	2.02	2.58	4.31	2.35	1.22	0.78	0	0
10	Chan	8.17	10.3	0.63	1.31	4.55	0.73	0.62	0.48	0	0
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LIVE SCOUR AT ABUTMENTS

Froehlich's Live-Bed Abutment Scour Equation — *LEFT* — *RIGHT* — ==========

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 1 =$ **2.68** **1.06** .....Eq. 7.1

Amended Local Scour Equation

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 0.05 =$ **1.73** **0.11** .....CT DOT DM Pg 9B-2

	LEFT	*RIGHT*		
Ys =	**1.66**	**0.61**	**m**	Scour depth <== using Amended equation
K_1 =	0.82	0.55		Coeffcient for abutment shape (see Table 7.1 and Figrue 7.6)
K_2 =	1.00	1.00		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
θ =	90	90		
				θ < 90 degrees if embankment points downstream
				θ > 90 degrees if embankment points upstream
				(see Figure 7.5 for definition of θ)
L' =	7.06	3.06	m	Length of active flow obstructed by the embankment (see Figure 7.4)
Ae =	8.83	16.26	m^2	Flow area of the approach cross section obstructed by the embankment
Fr =	0.21	0.01		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment
Ve =	0.63	0.08	m/s	Qe/Ae
Qe =	5.6034	1.3334	m^3/s	Flow obstructed by the abutment and approach embankment
Ya =	0.96	5.32	m	Ae/L, Average depth of flow on the floodplain
L =	9.241	3.0582	m	Length of embankment projected normal to the flow

Table 7.1. Abutment Shape Coefficients.

Description	K_1
Vertical-wall abutment	1.00
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

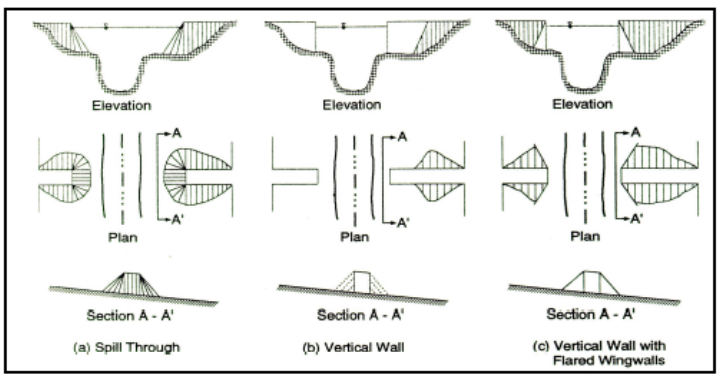


Figure 7.6. Abutment shape.

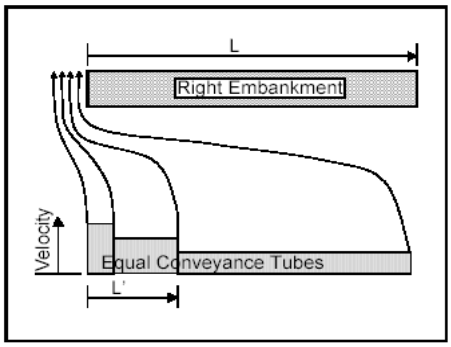


Figure 7.4. Determination of length of embankment blocking live flow for abutment scour estimation.

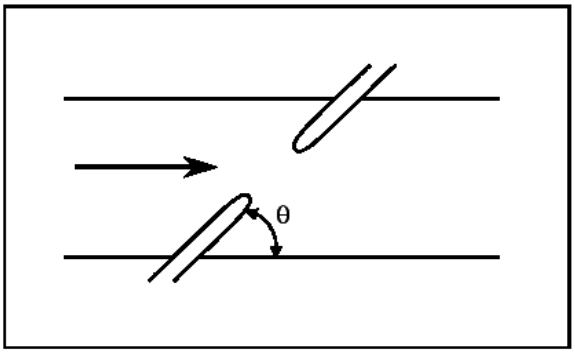


Figure 7.5. Orientation of embankment angle, θ, to the flow.

HIRE Live-Bed Abutment Scour Equation ==========

		LEFT	RIGHT	
Applicability check:	L/Y_1 =	4	1	*Use HIRE Eq. only if $L/Y_1 > 25$*
$Y_s/Y_1 = 4\ Fr^{0.33}\ K_1/0.55\ K_2$ =		**N/A**	**N/A**	.....Eq. 7.1

	LEFT	RIGHT		
Y_s =	**N/A**	**N/A**	**m**	Scour depth (N/A if $L/Y_1 < 25$)
K_1 =	0.82	0.55		Coeffcient for abutment shape (see Table 7.1 on RIGHT)
K_2 =	1.00	1.00		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
Y_1 =	2.27	5.32	m	Depth of flow at the abutment on the overbank or in the main channel,
Fr =	0.21	0.01		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment

Data Source

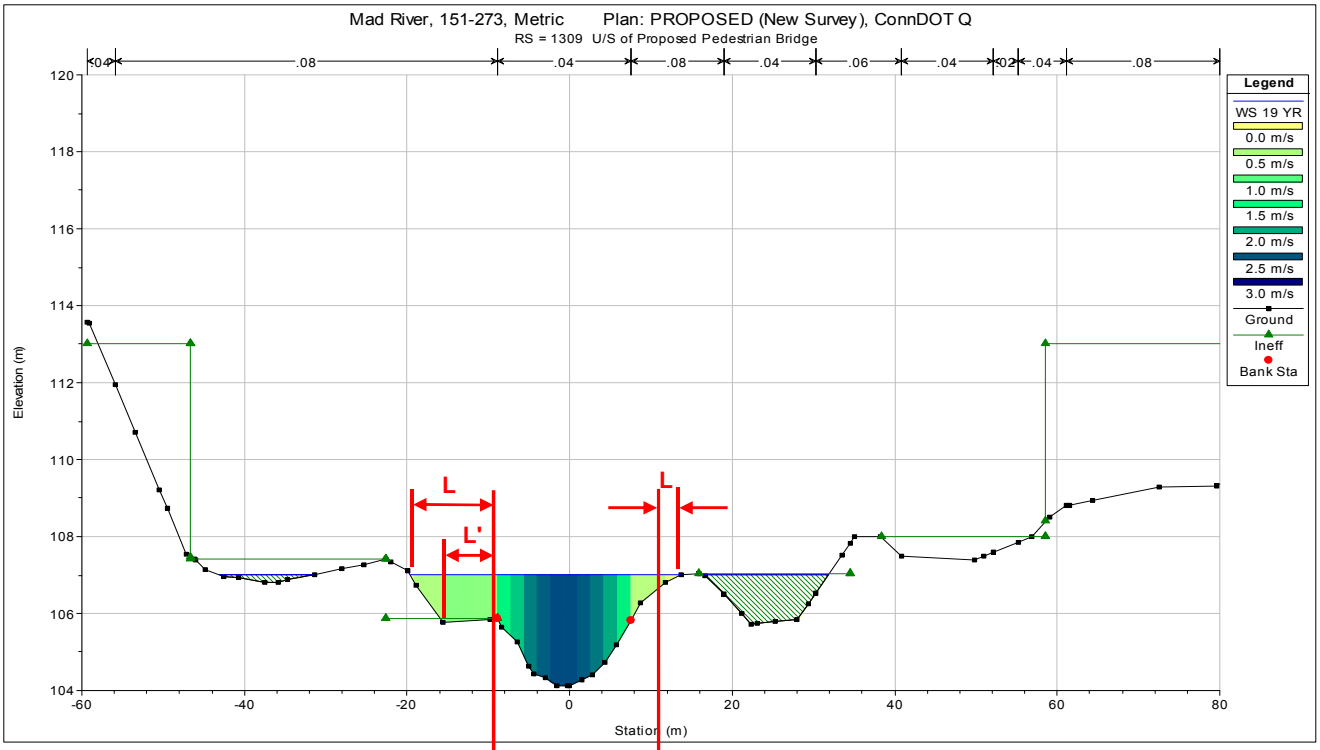
Eq. 7.1				From:	RS
	LT			UC	
		L' =	7.0616 m	D	1309
		Ae =	8.8326 m2	D	1309
		Qe =	5.6034 m3/s	D	1309
		L =	9.241 m	D	1309
	RT			UC	
		L' =	3.0582 m	D	1309
		Ae =	16.264 m2	D	1309
		Qe =	1.3334 m3/s	D	1309
		L =	3.0582 m	D	1309

Legends:

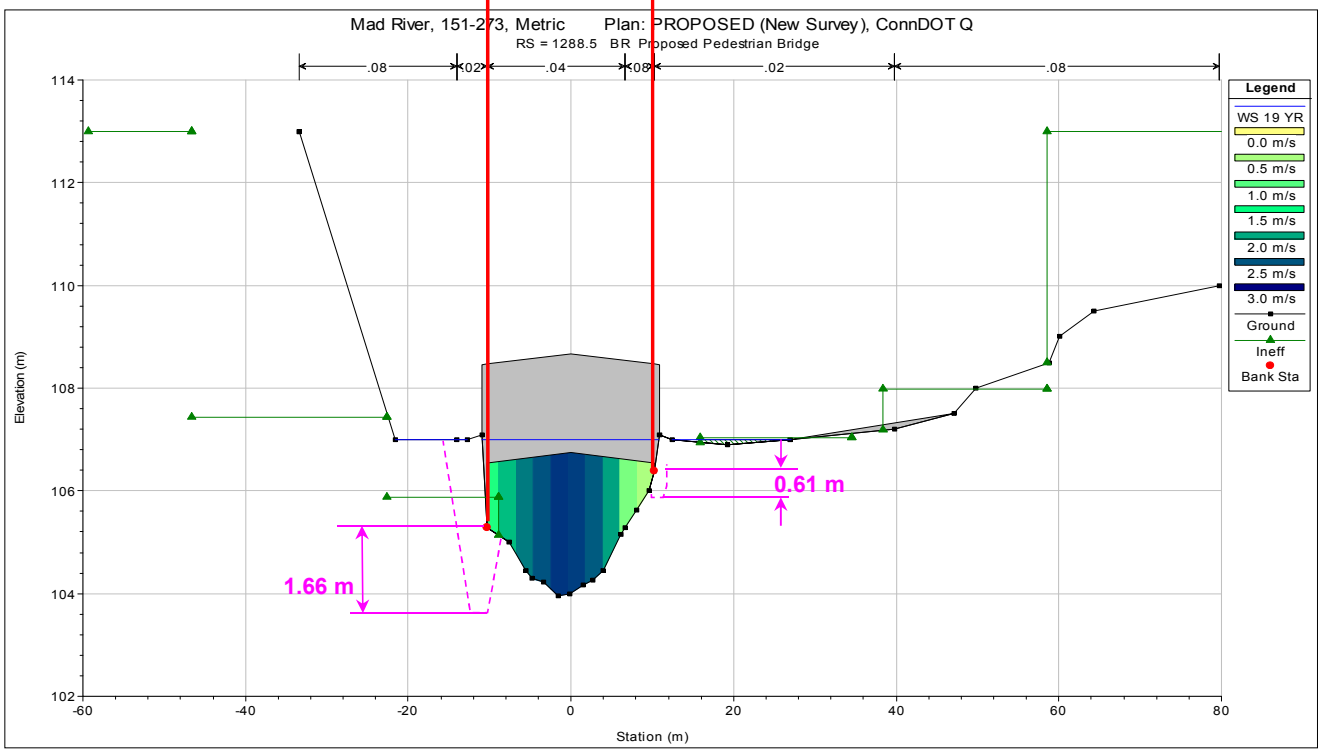
UC	from an upstream Cross Section output (approach section)
UF	from Bridge Upstream Face - Cross Section output (BR U); or Bridge Downstream Face (BR D) - this is seldom used
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections Used for Local Abutment Scour Computations

APPROACH SECTION 1309



BRIDGE SECTION 1288.5 BR U



** This drawing is intended to provide a basic, rough visualization of the scour depth. See Figure 5 for a more accurate depiction of combined total scour*

UPSTREAM APPROACH CHANNEL SECTION

River Station 1309 | Event: 19-YR(OVT)

CROSS SECTION OUTPUT | ***Use the same data as in the contraction scour computation?*** Yes | except channel stations

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 19 YR

E.G. Elev (m)	107.24	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.23	Wt. n-Val.	0.08	0.04	0.08	
W.S. Elev (m)	107	Reach Len. (m)	19	19	19	
Crit W.S. (m)	106.24	Flow Area (m2)	10.49	37.04	2.73	
E.G. Slope (m/m)	0.002803	Area (m2)	11.66	37.04	15.4	64.1
Q Total (m3/s)	90.66	Flow (m3/s)	6.75	82.88	1.03	
Top Width (m)	60	Top Width (m)	22.28	16.34	21.39	
Vel Total (m/s)	1.8	Avg. Vel. (m/s)	0.64	2.24	0.38	
Max Chl Dpth (m)	2.88	Hydr. Depth (m)	0.97	2.27	0.44	1.07
Conv. Total (m3/s)	1712.5	Conv. (m3/s)	127.4	1565.6	19.5	
Length Wtd. (m)	19	Wetted Per. (m)	10.96	16.85	6.3	
Min Ch El (m)	104.12	Shear (N/m2)	26.32	60.41	11.9	
Alpha	1.42	Stream Power (N/m s)	5742.47	0	0	
Frctn Loss (m)		Cum Volume (1000 m3)	0.2	18.12	0.24	
C & E Loss (m)		Cum SA (1000 m2)	0.63	10.39	0.74	

		Flow dis.	*manual*
Left WS Sta.			-19.53
Left Flood Sta.		-15.73	-17.35
Left Abutmnt Sta.		-10.29	
Right Abutmnt Sta.		10.29	
Right Flood Sta.		11.73	13.35
Right WS Sta.			13.35
L' (left)	7.06	L (left)	9.241
L' (Right)	3.0582	L (Right)	3.0582

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT		5.603	8.8326		
Main	20.5808	84.703	40.3738	1.96	2.10
Right		1.3334	16.2636		

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 19 YR

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	LOB	-43.17	-39.75	0	0.18	3.31	0	0.05	0	1.5	
2	LOB	-39.75	-36.32	0	0.53	3.43	0	0.15	0	4.23	
3	LOB	-36.32	-32.9	0	0.42	3.43	0	0.12	0	3.36	
4	LOB	-32.9	-29.47	0	0.04	1.34	0	0.03	0	0.72	
5	LOB	-29.47	-26.05							0	
6	LOB	-26.05	-22.62							0	
7	LOB	-22.62	-19.18	0	0.04	0.47	0	0.08	0.11	2.1	
8	LOB	-19.18	-15.73	1.11	2.36	3.59	1.23	0.68	0.47	18.03	
9	LOB	-15.73	-12.29	2.91	4.13	3.45	3.21	1.2	0.7	32.9	
10	LOB	-12.29	-8.84	2.73	3.97	3.45	3.01	1.15	0.69	31.68	
11	Chan	-8.84	-7.21	3.59	2.3	1.71	3.96	1.41	1.56	37.01	
12	Chan	-7.21	-5.57	5.34	2.94	1.74	5.89	1.8	1.82	46.49	
13	Chan	-5.57	-3.94	8.91	3.98	1.71	9.83	2.43	2.24	63.77	
14	Chan	-3.94	-2.3	10.66	4.35	1.64	11.75	2.66	2.45	72.79	
15	Chan	-2.3	-0.67	11.92	4.65	1.64	13.15	2.85	2.56	77.91	
16	Chan	-0.67	0.96	11.9	4.65	1.64	13.12	2.84	2.56	77.91	
17	Chan	0.96	2.6	10.86	4.4	1.64	11.98	2.69	2.47	73.67	
18	Chan	2.6	4.23	9.21	4.01	1.67	10.16	2.46	2.3	66.12	
19	Chan	4.23	5.87	6.65	3.33	1.71	7.34	2.04	2	53.63	
20	Chan	5.87	7.5	3.85	2.42	1.74	4.24	1.48	1.59	38.1	
21	ROB	7.5	11.73	1.01	2.54	4.36	1.11	0.6	0.4	15.99	
22	ROB	11.73	15.97	0.02	0.19	1.94	0.03	0.1	0.12	2.67	
23	ROB	15.97	22.14	0	3.29	5.66	0	0.6	0	16	
24	ROB	22.14	28.3	0	7.46	6.19	0	1.21	0	33.15	
25	ROB	28.3	34.47	0	1.92	3.69	0	0.54	0	14.27	
26	ROB	7.5	10.32	0.87	2	2.93	0.96	0.71	0.44		
27	ROB	10.32	13.15	0.1	0.54	2.85	0.11	0.19	0.19		
28	ROB	13.15	15.97	0	0	0.2	0	0.01	0.03		
29	ROB	15.97	18.61	0	0.02	0.58	0	0.03	0		
30	ROB	18.61	21.26	0	0.48	2.65	0	0.18	0		
31	ROB	21.26	23.9	0	0.88	2.64	0	0.33	0		
32	ROB	23.9	26.54	0	1.1	2.65	0	0.42	0		
33	ROB	26.54	29.18	0	0.64	2.63	0	0.25	0		
34											
35											
36											
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	Left	Right
Computed L' = Q_e/q_{tube} =	***7.06163***	***5.56***
Q_e:	5.60	1.33
V_{tube}:	0.69	0.4
y_{tube}:	1.15	0.6
q_{tube}:	0.7935	0.24

BRIDGE SECTION

CROSS SECTION OUTPUT — ***River Station*** 1288.5 BR U

Use the same data as in the contraction scour computation? Yes

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 19 YR

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	107.24	Element				
Vel Head (m)	0.27	Wt. n-Val.				
W.S. Elev (m)	107	Reach Len. (m)	3.5	3.5	3.5	
Crit W.S. (m)	105.96	Flow Area (m2)	2.5	39.41	4.61	
E.G. Slope (m/m)		Area (m2)	0.01	39.41	0.82	40.24
Q Total (m3/s)	90.66	Flow (m3/s)	1.73	85.92	2.95	
Top Width (m)	23.53	Top Width (m)	8.89		14.64	
Vel Total (m/s)	1.95	Avg. Vel. (m/s)	0.69	2.18	0.64	
Max Chl Dpth (m)	3.04	Hydr. Depth (m)	0.28		1.29	1.71
Conv. Total (m3/s)		Conv. (m3/s)				
Length Wtd. (m)	3.5	Wetted Per. (m)	8.89	43.07	3.58	
Min Ch El (m)	103.96	Shear (N/m2)				
Alpha	1	Stream Power (N/m s)	3816.83	0	0	
Frctn Loss (m)		Cum Volume (1000 m3)	0.09	17.39	0.08	
C & E Loss (m)		Cum SA (1000 m2)	0.34	10.23	0.39	

		Flow dis.	*manual*
Left WS Sta.			-10.3
Left Flood Sta.			-10.3
Left Abutmnt Sta.		-10.3	
Right Abutmnt Sta.		10.3	
Right Flood Sta.			10.3
Right WS Sta.			10.3
L' (left)	0	L (left)	0
L' (Right)	0	L (Right)	0

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1
LEFT					
Main	20.6	85.93	39.41	1.91	2.18
Right					

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 19 YR

Pos		Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)
1	Chan	-10.3	-8.84	2.6	1.96	4.18	3.02	1.34	1.33	0	0
2	Chan	-8.84	-6.71	6.39	3.4	4.29	7.44	1.6	1.88	0	0
3	Chan	-6.71	-4.59	10.3	4.54	4.31	11.98	2.13	2.27	0	0
4	Chan	-4.59	-2.46	13.09	5.22	4.27	15.24	2.45	2.51	0	0
5	Chan	-2.46	-0.33	15.54	5.78	4.26	18.08	2.72	2.69	0	0
6	Chan	-0.33	1.79	14.78	5.61	4.26	17.2	2.64	2.64	0	0
7	Chan	1.79	3.92	12.52	5.08	4.27	14.57	2.39	2.46	0	0
8	Chan	3.92	6.05	8.06	3.93	4.36	9.38	1.85	2.05	0	0
9	Chan	6.05	8.17	2.02	2.58	4.31	2.35	1.22	0.78	0	0
10	Chan	8.17	10.3	0.63	1.31	4.55	0.73	0.62	0.48	0	0
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

BRIDGE OUTPUT

River Station 1288.5

Low Chord Elev.	106.54
Mean Channelbed Elev.	104.63
Bridge Opening Width	20.6

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 Profile: 19 YR

			Inside BR US	Inside BR DS
E.G. US. (m)	107.24	Element		
W.S. US. (m)	107	E.G. Elev (m)	107.24	107.23
Q Total (m3/s)	90.66	W.S. Elev (m)	107	107
Q Bridge (m3/s)	85.92	Crit W.S. (m)	105.96	105.96
Q Weir (m3/s)	4.74	Max Chl Dpth (m)	3.04	3.04
Weir Sta Lft (m)	-22.03	Vel Total (m/s)	1.95	1.98
Weir Sta Rgt (m)	36.5	Flow Area (m2)	46.52	45.84
Weir Submerg	0	Froude # Chl	0.42	0.42
Weir Max Depth (m)	0.29	Specif Force (m3)	77.1	77.1
Min El Weir Flow (m)	106.97	Hydr Depth (m)	3.73	2.76
Min El Prs (m)	106.74	W.P. Total (m)	55.54	59.67
Delta EG (m)	0.39	Conv. Total (m3/s)		
Delta WS (m)	0.33	Top Width (m)	23.53	16.6
BR Open Area (m2)	39.41	Frctn Loss (m)		
BR Open Vel (m/s)	2.18	C & E Loss (m)		
Coef of Q		Shear Total (N/m2)		
Br Sel Method	Press/Weir	Power Total (N/m s)	-1599.12	-1549.33

Height of Vertical Exposed Face of Abutment	0.75	
Approx. Side Slope of channel below bridge	4	:1 (h:v)
Approx. channel bottpm width	6.40	
Hydraulic depth to mean bed elevation	2.52	
Hydraulic depth	1.91	

PRESSURE FLOW SCOUR

Live-Bed Vertical Contraction Scour ==========

$Y_s/Y_1 = -5.08 + 1.27 (Y_1 / H_b) + 4.44 (H_b / Y_1) + 0.19 (V_a / V_c) =$ **0.26 m** .....Eq. 6.21 (Arneson's Eq.)

Y_s =	**0.61 m**	Depth of vertical contraction scour relative to mean bed elevation
Y_1 =	2.37 m	Depth of flow immediately upstream of the bridge (hydraulic depth at upstream face)
H_b =	1.91 m	Distance from the low chord of the bridge to the average elevation of the stream bed before scour
V_a =	1.97 m/s	Average velocity of the flow through the bridge opening before scour occurs
V_c =	2.05 m/s	Critical velocity of the D_{50} of the bed material in the bridge opening
D_{50} = (Design)	m	if different from the value used in the Contraction Scour computation

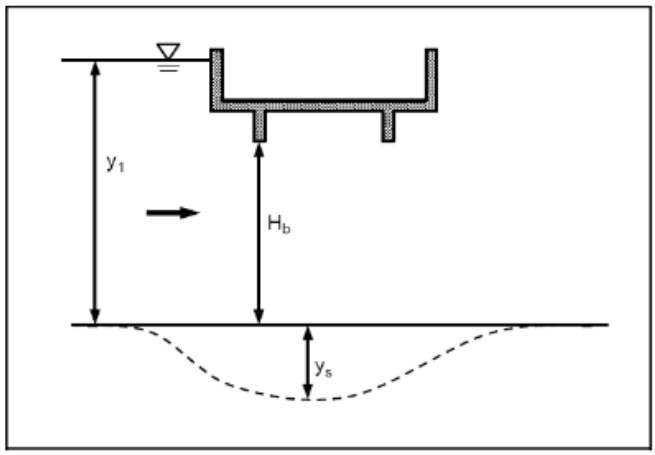
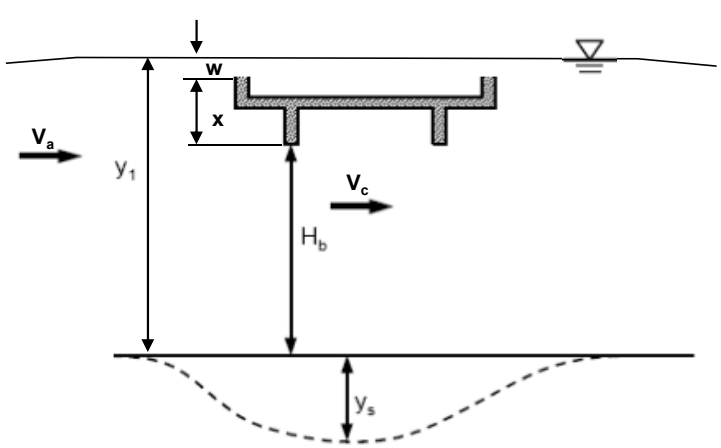


Figure 6.14. Definition sketch of vertical contraction scour resulting from pressure flow.

Clear-Water Contraction Scour ==========

$H_b + Y_s/Y_a = 1.1021 [(1 - w / Y_a) V_a / V_c]^{0.6031} =$ **1.01 m** .....HEC-18 (1995), App. B (Umbrell)

Y_s =	**0.00 m**	Depth of vertical scour **LIVE-BED controls. Ignore this procedure**
Y_a =	2.37 m	Depth of flow immediately upstream of the bridge (approch depth)
H_b =	1.91 m	Depth from the low chord of the bridge to original river bed
V_a =	1.8 m/s	Approach Velocity
V_c =	2.05 m/s	Velocity under the bridge deck. (V_c is equal to the incipient motion velocity)
w =	0.03 m	Depth of overflow



PROJECT NO. 151-273 **BRIDGE NO.** Pedestrian Crossing **UNIT:** Metric

Ref. HEC-18., May 2001 (4th ed.)

(October 2013 Note: These equation are still valid in HEC-18, 5th ed.)

SUMMARY

Contraction Scour		Type:	**LIVE-BED**	Depth:	**0.14** m	Event:	**50-YR**
Local	**East Abut. #2**	**LEFT**	Eq.: Froehlich	Depth:	**1.58** m	Event:	**50-YR**
Abutment	**West Abut. #1**	**RIGHT**	Eq.: Froehlich	Depth:	**0.48** m	Event:	**50-YR**

CONTRACTION SCOUR

$V_c = K_u\, y^{1/6}\, D^{1/3}$ .....Eq. 5.1

= 2.03 *m/s* Critacal velocity above which bed material of size D and smaller will be transported

Ku = 6.19 m (6.19 in SI units; 11.17 in English units)

y = 2.18 m Average depth of flow upstream of the bridge

D = 0.024 m Particle size for Vc , *m* (use D_{50})

V = 2.50 *m/s* The mean velocity of the flow in the main channel or overbank area upstream of the brige opening

Vc < V ***Thus, LIVE-BED CONTRACTION SCOUR***

Live-Bed Contraction Scour ==========

$Y_2/Y_1 = (Q_2/Q_1)^{6/7}\,(W_1/W_2)^{k_1}$ = 0.94 .....Eq. 5.2

$Y_s = Y_2 - Y_o$ m .....Eq. 5.3

= 0.14 m Average contraction scour depth

Y_1 = 2.18 m Average depth in the upstream main channel

Y_2 = 2.05 m Average depth in the contracted section

Y_o = 1.91 m Existing depth in the contracted section before scour

Q_1 = 90.35 m3/s Flow in the upstream channel transporting sediment

Q_2 = 98.49 m3/s Flow in the contracted channel

W_1 = 16.34 m Bottom width of the upstream main channel that is transporting bed material

W_2 = 20.60 m Bottom width of the main channel in the contracted section less pier width

k_1 = 0.59 Exponent determined below (V^*/ω = 0.42)

V^* = 0.2674 $=(T_o/\rho)^{1/2}$ or $(gY1\ S1)^{1/2}$, shear velocity in the upstream section , m/s

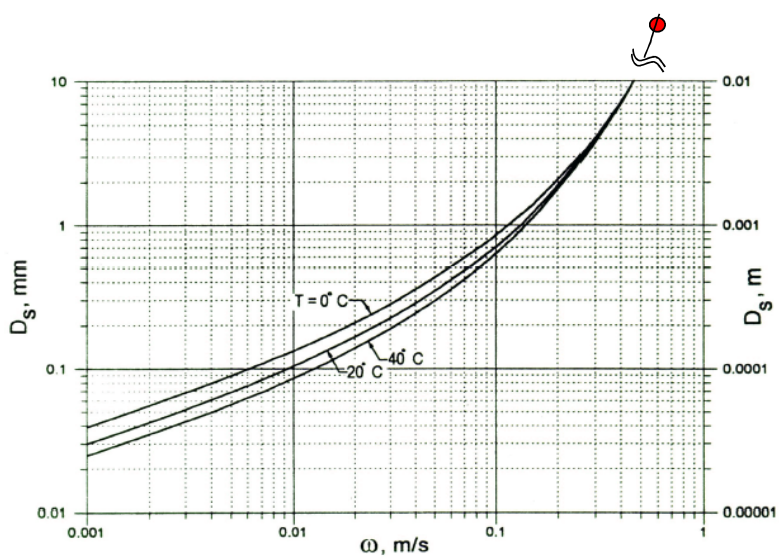
ω = 0.63 m/s Fall velocity of bed material based on the D_{50} (Figure 5.8)

g = 9.81 m/s^2 Acceleration of gravity

S1 = 0.002715 m/m Slope of energy gradeline of main channel

T_o = 71.51 Pa (N/m^2) Shear stess on the bed

ρ = 1000 kg/m^3 Density of water



V^*/ω	k1	*Mode of Bed Material Transport*
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

Figure 5.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Clear-Water Contraction Scour ==========

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2} \right]^{3/7}$$ .....Eq. 5.4

$$y_s = y_2 - y_o$$ m .....Eq. 5.5

=	N/A	m	Average contraction scour depth **LIVE-BED controls. Ignore this procedure**
y_2 =	2.14	m	Average equilibrium depth in the contracted section after contraction scour
y_o =	1.91	m	Average existing depth in the contracted section
Q =	98.47	m3/s	Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W
W =	20.60	m	Bottom width of the contracted section less pier widths
K_u =	0.0250		(0.025 in SI units; 0.0077 in English units)
D_m =	0.0300	m	Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in th contacted setion
D_{50} =	0.0240	m	Median diameter of bed material

Because D_{50} is not the largest particle in the bed material, the scoured section can be slightly armored. Therefore, the D_m is assumed to be 1.25 D_{50}. For stratified bed material the depth of scour can be determined by using the clear-water scour equation sequentially with successive D_m of the bed material layers.

Data Source

Eq. 5.1			From:	RS
y =	2.18	m	D	1309
V =	2.50	m	D	1288.5 BR U

Eq. 5.2 & 5.3				
Y1 =	2.18	m	D	1309
Yo =	1.91	m	D	1288.5 BR U
Q1 =	90.35078	m3/s	D	1309
Q2 =	98.49	m3/s	D	1288.5 BR U
W1 =	16.34	m	D	1309
or (n/a)		m (manual)		
W2 =	20.6	m	D	1288.5 BR U
or (n/a)		m (manual)		
S1 =	0.002715	m/m	C	1309
To =	71.51	Pa (N/m^2)	C	1309
P2 =	0	m (pier width)		

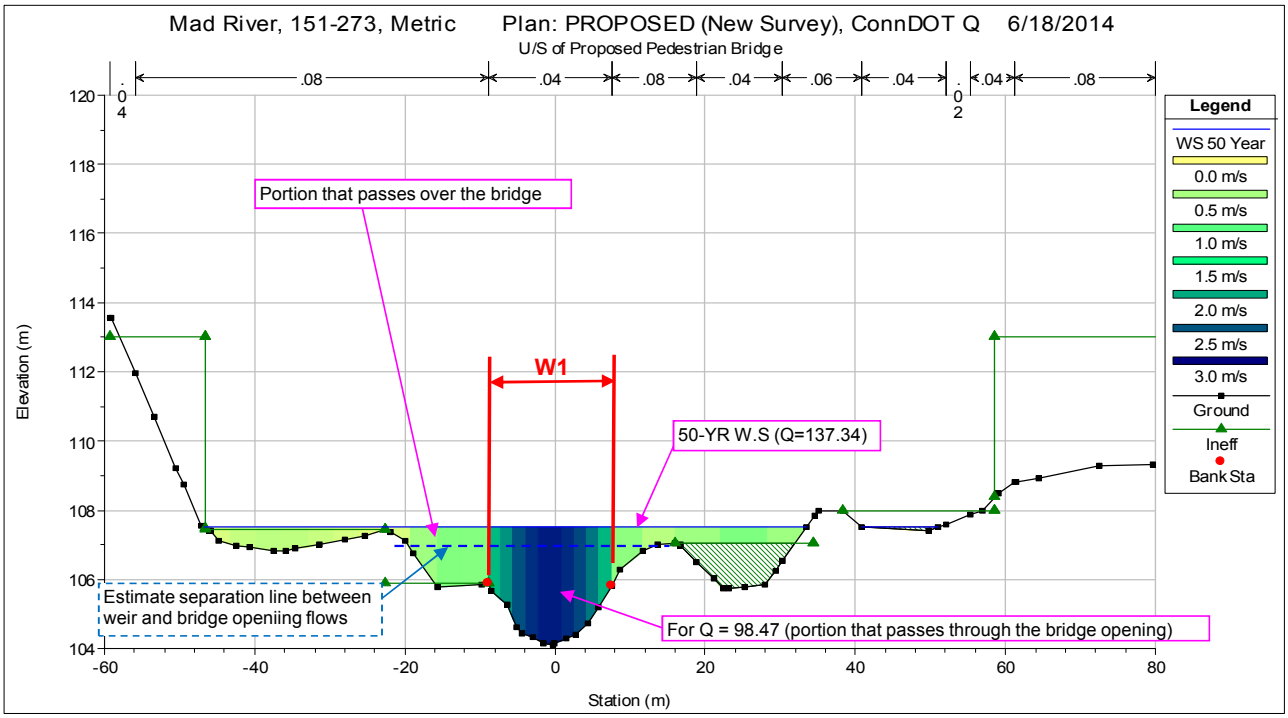
Eq. 5.4 & 5.5				
Q =	98.47	m3/s	C	1288.5
W =	20.6	m	C	1288.5
yo =	1.91	m	C	1288.5

Legends:

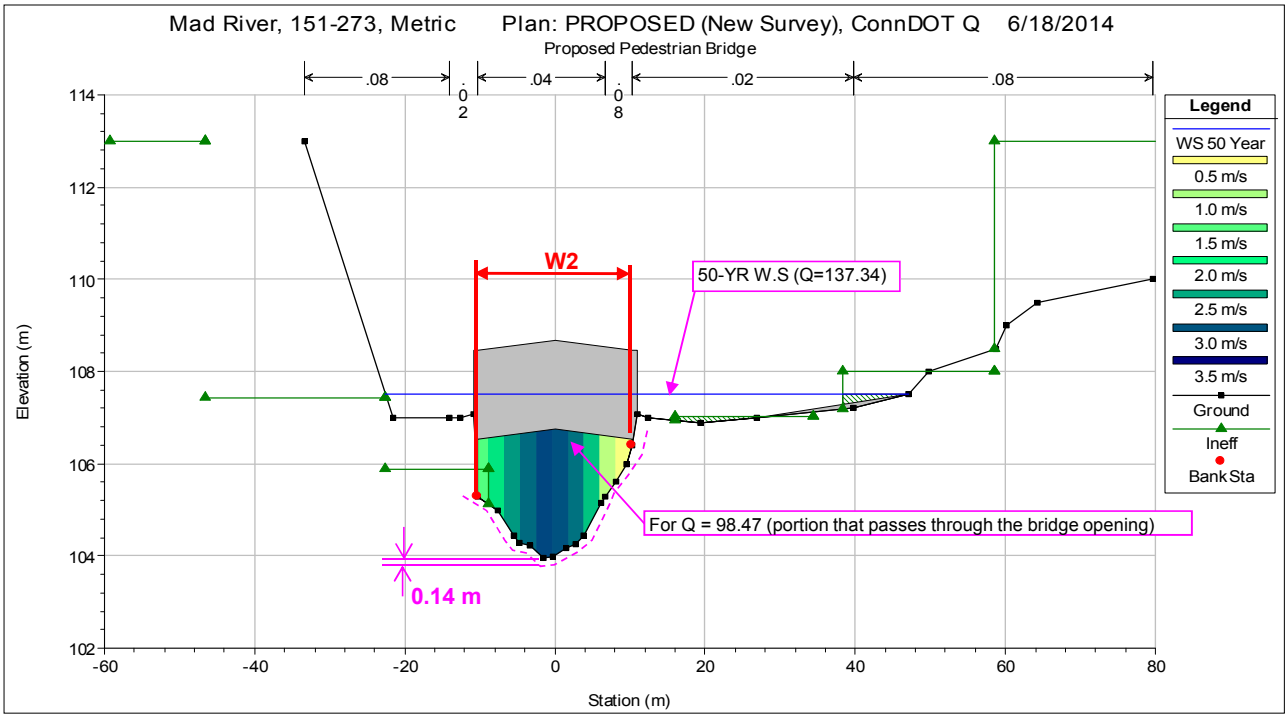
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections used for Contraction Scour Computations

UPSTREAM SECTION 1309



CONTRACTED SECTION 1288.5 BR U



*This drawing is intended to provide a basic, rough visualization of the scour depth. See Figure 5 for a more accurate depiction.

UPSTREAM CHANNEL SECTION

River Station 1309 Event: 50-YR

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computation*** No except channel stations

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 50 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	107.8	Element				
Vel Head (m)	0.27	Wt. n-Val.	0.08	0.04	0.06	
W.S. Elev (m)	107.5	Reach Len. (m)	19	19	19	
Crit W.S. (m)	106.68	Flow Area (m2)	27.42	45.26	14.87	
E.G. Slope (m/m)	0.002715	Area (m2)	27.42	45.26	28.54	101.22
Q Total (m3/s)	137.34	Flow (m3/s)	14.36	113.91	9.07	
Top Width (m)	90.46	Top Width (m)	37.95	16.34	36.17	
Vel Total (m/s)	1.57	Avg. Vel. (m/s)	0.52	2.52	0.61	
Max Chl Dpth (m)	3.38	Hydr. Depth (m)	0.73	2.77	0.57	1.12
Conv. Total (m3/s	2635.7	Conv. (m3/s)	275.5	2186.1	174.1	
Length Wtd. (m)	19	Wetted Per. (m)	38.04	16.85	26.48	
Min Ch El (m)	104.12	Shear (N/m2)	19.19	71.51	14.95	
Alpha	2.16	Stream Power (N/m s)	5742.47	0	0	
Frctn Loss (m)		Cum Volume (1000 m3	1.12	24.51	0.85	
C & E Loss (m)		Cum SA (1000 m2)	5.75	11.5	1.58	

	Flow dis. (data)	*manual*	Overflow?	YES
Left WS Sta.		-46.79	-19.37	Flow through the bridge opening only
Left Flood Sta.	-19.18		-19.37	
Left Main Channel	-8.84			
Right Main Channel	7.5			
Right Flood Sta.	11.73		12.74	
Right WS Sta.		33.46	12.74	
L' (left) 10.53	L (left)	10.53		
L' (Right) 5.24	L (Right)	5.24		

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT		14.34	27.4			6.72	9.93
Main	16.34	113.91	45.26	2.18	2.52	90.35	35.65
Right		9.07	14.87			1.42	2.18

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 50 Year

Overflow Separation. Elev. (est.) 106.912 Ave. Dept 0.588

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Elev. (est.)	Ave. Dept
1	LOB	-49.79	-46.6	0	0	0.19	0	0.01	0	0.34	0	0.00	0.00
2	LOB	-46.6	-43.17	0.23	1.02	3.47	0.17	0.3	0.23	7.86	1.78	0.00	0.00
3	LOB	-43.17	-39.75	0.66	1.9	3.43	0.48	0.56	0.35	14.78	5.12	0.00	0.00
4	LOB	-39.75	-36.32	0.87	2.25	3.43	0.63	0.66	0.39	17.48	6.77	0.08	0.23
5	LOB	-36.32	-32.9	0.8	2.14	3.43	0.58	0.63	0.37	16.63	6.23	0.06	0.13
6	LOB	-32.9	-29.47	0.52	1.66	3.43	0.38	0.48	0.32	12.9	4.08	0.00	0.00
7	LOB	-29.47	-26.05	0.28	1.15	3.43	0.21	0.34	0.25	8.92	2.21	0.00	0.00
8	LOB	-26.05	-22.62	0.1	0.61	3.43	0.07	0.18	0.16	4.74	0.77	0.00	0.00
9	LOB	-22.62	-19.18	0.23	1.02	3.51	0.17	0.3	0.23	7.77	1.75	0.00	0.00
10	LOB	-19.18	-15.73	2.28	4.09	3.59	1.66	1.19	0.56	30.3	16.92	1.14	2.06
11	LOB	-15.73	-12.29	4.28	5.86	3.45	3.11	1.7	0.73	45.24	33.01	2.80	3.84
12	LOB	-12.29	-8.84	4.09	5.7	3.45	2.98	1.66	0.72	44.08	31.61	2.63	3.67
13	Chan	-8.84	-7.21	5.94	3.12	1.71	4.32	1.91	1.9	48.64	92.45	4.12	2.16
14	Chan	-7.21	-5.57	8.01	3.76	1.74	5.83	2.3	2.13	57.62	122.58	5.96	2.80
15	Chan	-5.57	-3.94	12.12	4.8	1.71	8.82	2.94	2.53	74.55	188.31	9.70	3.84
16	Chan	-3.94	-2.3	14.14	5.18	1.64	10.29	3.17	2.73	83.83	229	11.51	4.22
17	Chan	-2.3	-0.67	15.54	5.48	1.64	11.32	3.35	2.84	88.81	252.1	12.82	4.52
18	Chan	-0.67	0.96	15.52	5.47	1.64	11.3	3.35	2.84	88.83	252.19	12.80	4.51
19	Chan	0.96	2.6	14.36	5.22	1.64	10.46	3.2	2.75	84.69	232.93	11.71	4.26
20	Chan	2.6	4.23	12.5	4.84	1.67	9.1	2.96	2.58	77.17	199.47	10.03	3.88
21	Chan	4.23	5.87	9.55	4.15	1.71	6.96	2.54	2.3	64.77	148.99	7.33	3.19
22	Chan	5.87	7.5	6.23	3.24	1.74	4.53	1.98	1.92	49.45	95.01	4.39	2.28
23	ROB	7.5	11.73	3.06	4.67	4.36	2.23	1.1	0.66	28.49	18.7	1.42	2.18
24	ROB	11.73	15.97	0.94	2.28	4.25	0.69	0.54	0.41	14.27	5.91	0.00	0.00
25	ROB	15.97	22.14	1.67	2.92	6.3	1.22	0.47	0.57	12.36	7.06	0.00	0.00
26	ROB	22.14	28.3	2.23	2.92	6.19	1.62	0.47	0.76	12.58	9.58	0.00	0.00
27	ROB	28.3	34.47	1.17	2.08	5.39	0.85	0.4	0.56	10.28	5.78	0.00	0.00
28	ROB	34.47	38.34							0	0	0	0
29	ROB	38.34	43.4	0	0.05	2.57	0	0.02	0	0.48	0	0	0
30	ROB	43.4	48.47	0	0.31	5.07	0	0.06	0	1.62	0	0	0
31	ROB	48.47	53.53	0	0.19	2.59	0	0.08	0	2	0	0	0
32												**98.49**	
33												Q Bridge	
34												98.47	
35													
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CONTRACTED CHANNEL SECTION

River Station 1288.5 BR U

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 50 Year

E.G. Elev (m)	107.77	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.32	Wt. n-Val.				
W.S. Elev (m)	107.5	Reach Len. (m)	3.5	3.5	3.5	
Crit W.S. (m)	106.38	Flow Area (m2)	8.78	39.41	19.34	
E.G. Slope (m/m)		Area (m2)	5.55	39.41	13.97	58.93
Q Total (m3/s)	137.34	Flow (m3/s)	10.95	98.47	23.67	
Top Width (m)	47.93	Top Width (m)	11.65		36.27	
Vel Total (m/s)	2.03	Avg. Vel. (m/s)	1.25	2.5	1.22	
Max Chl Dpth (m)	3.54	Hydr. Depth (m)	0.75		0.7	1.23
Conv. Total (m3/s		Conv. (m3/s)				
Length Wtd. (m)	3.5	Wetted Per. (m)	12.2	43.07	27.87	
Min Ch El (m)	103.96	Shear (N/m2)				
Alpha	1.08	Stream Power (N/m s)	3816.83	0	0	
Frctn Loss (m)		Cum Volume (1000 m3	0.81	23.7	0.44	
C & E Loss (m)		Cum SA (1000 m2)	5.28	11.34	0.9	

		Flow dis.	*manual*	
	Left WS Sta.		-10.3	8.17
	Left Flood Sta.			8.17
	Left Main Channel	-10.3		
	Right Main Channel	10.3		
	Right Flood Sta.			0
	Right WS Sta.		10.3	0
L' (left)	-10.3	L (left)	0	
L' (Right)	-10.3	L (Right)	0	

Overflow? YES

Flow through the bridge opening only

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT							
Main	20.6	98.49	39.41	1.91	2.50	98.49	39.41
Right							

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 50 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 107.5	Ave. Dept 0
1	Chan	-10.3	-8.84	2.98	1.96	4.18	3.02	1.34	1.52	0	0	2.98	1.96
2	Chan	-8.84	-6.71	7.33	3.4	4.29	7.44	1.6	2.15	0	0	7.33	3.40
3	Chan	-6.71	-4.59	11.8	4.54	4.31	11.98	2.13	2.6	0	0	11.80	4.54
4	Chan	-4.59	-2.46	15.01	5.22	4.27	15.24	2.45	2.88	0	0	15.01	5.22
5	Chan	-2.46	-0.33	17.81	5.78	4.26	18.08	2.72	3.08	0	0	17.81	5.78
6	Chan	-0.33	1.79	16.94	5.61	4.26	17.2	2.64	3.02	0	0	16.94	5.61
7	Chan	1.79	3.92	14.35	5.08	4.27	14.57	2.39	2.82	0	0	14.35	5.08
8	Chan	3.92	6.05	9.24	3.93	4.36	9.38	1.85	2.35	0	0	9.24	3.93
9	Chan	6.05	8.17	2.31	2.58	4.31	2.35	1.22	0.89	0	0	2.31	2.58
10	Chan	8.17	10.3	0.72	1.31	4.55	0.73	0.62	0.55	0	0	0.72	1.31
11												**98.49**	
12												Q Bridge	
13												98.47	
14													
15													
16													
17													
18													
19													
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LIVE SCOUR AT ABUTMENTS

Froehlich's Live-Bed Abutment Scour Equation — *LEFT* — *RIGHT* — ==========

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 1 =$ — **2.66** — **2.52** — .....Eq. 7.1

Amended Local Scour Equation

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 0.05 =$ — **1.71** — **1.57** — .....CT DOT DM Pg 9B-2

	LEFT	*RIGHT*		
Ys =	**1.58**	**0.48**	**m**	Scour depth <== using Amended equation
K_1 =	1.00	0.82		Coeffcient for abutment shape (see Table 7.1 and Figrue 7.6)
K_2 =	0.91	1.06		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
θ =	43	138		
				θ < 90 degrees if embankment points downstream
				θ > 90 degrees if embankment points upstream
				(see Figure 7.5 for definition of θ)
L' =	4.70	0.66	m	Length of active flow obstructed by the embankment (see Figure 7.4)
Ae =	8.39	0.74	m^2	Flow area of the approach cross section obstructed by the embankment
Fr =	0.22	0.38		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment
Ve =	0.67	0.65	m/s	Qe/Ae
Qe =	5.611832	0.482263	m^3/s	Flow obstructed by the abutment and approach embankment
Ya =	0.92	0.30	m	Ae/L, Average depth of flow on the floodplain
L =	9.081	2.4482	m	Length of embankment projected normal to the flow

Table 7.1. Abutment Shape Coefficients.

Description	K_1
Vertical-wall abutment	1.00
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

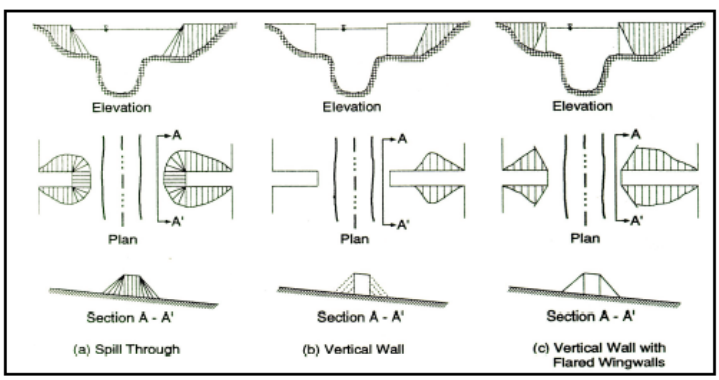


Figure 7.6. Abutment shape.

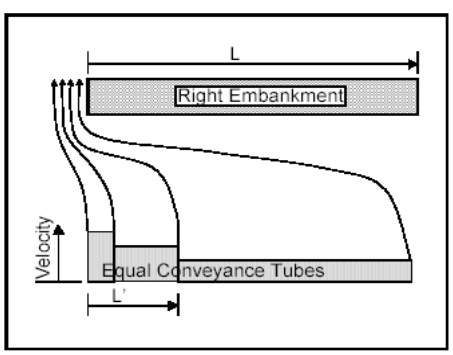


Figure 7.4. Determination of length of embankment blocking live flow for abutment scour estimation.

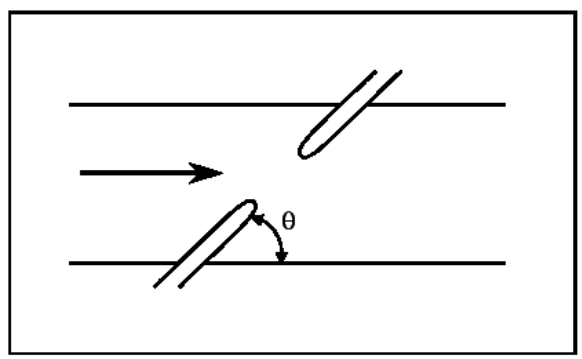


Figure 7.5. Orientation of embankment angle, θ, to the flow.

HIRE Live-Bed Abutment Scour Equation ==========

		LEFT	RIGHT	
Applicability check:	L/Y_1 =	4	1	*Use HIRE Eq. only if $L/Y_1 > 25$*
$Y_s/Y_1 = 4\ Fr^{0.33}\ K_1/0.55\ K_2$ =		**N/A**	**N/A**	.....Eq. 7.1

	LEFT	RIGHT		
Y_s =	**N/A**	**N/A**	**m**	Scour depth (N/A if $L/Y_1 < 25$)
K1 =	1.00	0.82		Coeffcient for abutment shape (see Table 7.1 on RIGHT)
K2 =	0.91	1.06		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
Y1 =	2.18	2.18	m	Depth of flow at the abutment on the overbank or in the main channel,
Fr =	0.22	0.38		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment

Data Source

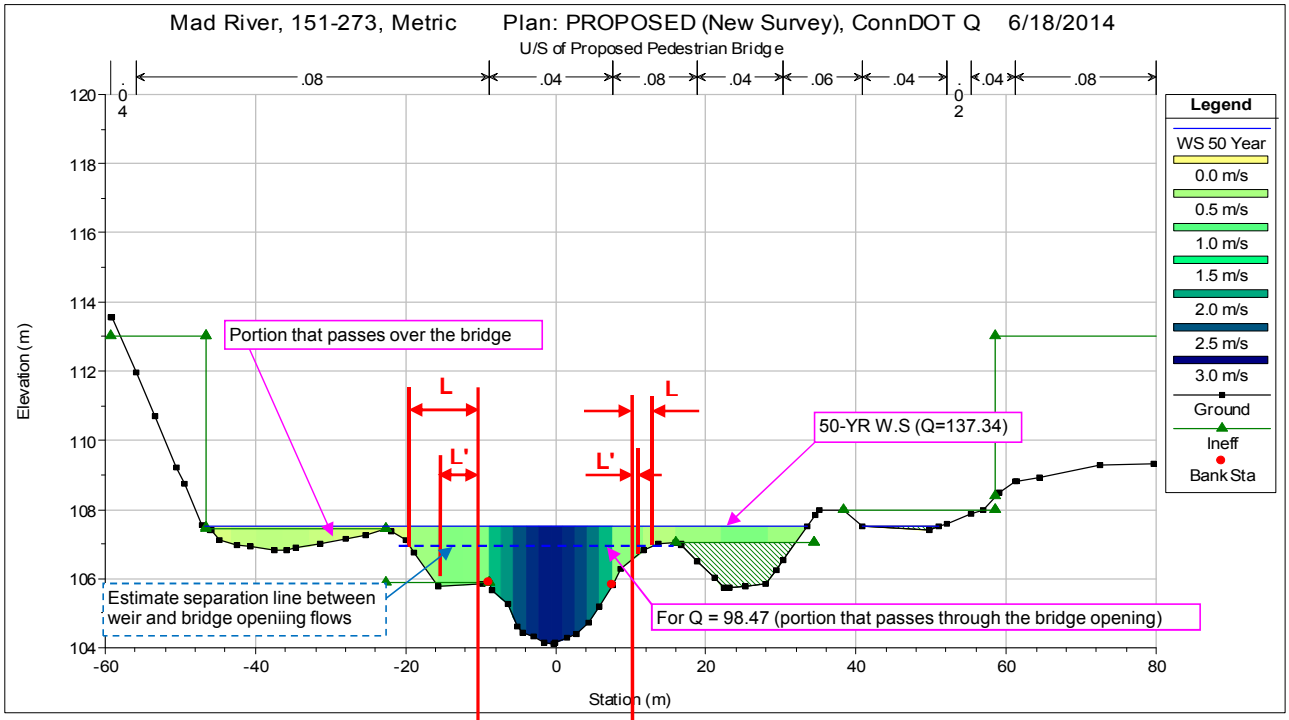
Eq. 7.1			From:	RS
LT			UC	
	L' =	4.6953 m	D	1309
	Ae =	8.3903 m2	D	1309
	Qe =	5.6118 m3/s	D	1309
	L =	9.081 m	D	1309
RT			UC	
	L' =	0.6643 m	D	1309
	Ae =	0.7421 m2	D	1309
	Qe =	0.4823 m3/s	D	1309
	L =	2.4482 m	D	1309

Legends:

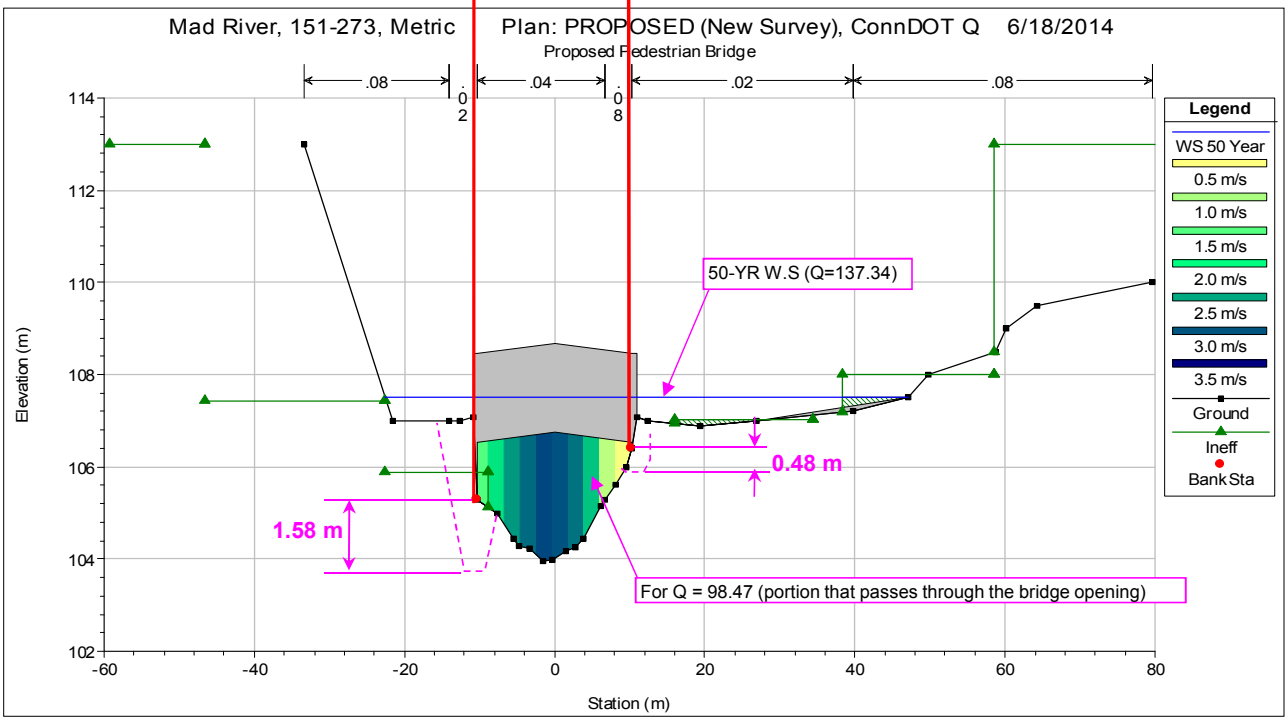
UC	from an upstream Cross Section output (approach section)
UF	from Bridge Upstream Face - Cross Section output (BR U); or Bridge Downstream Face (BR D) - this is seldom used
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections Used for Local Abutment Scour Computations

APPROACH SECTION 1309



1288.5 BR U **1288.5 BR U**



** This drawing is intended to provide a basic, rough visualization of the scour depth. See Figure 5 for a more accurate depiction of combined total scour*

UPSTREAM APPROACH CHANNEL SECTIO *River Station* 1309 Event: 50-YR

CROSS SECTION OUTPUT *Use the same data as in the contraction scour computati* YES except channel stations

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 50 Year

E.G. Elev (m)	107.8	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.27	Wt. n-Val.	0.08	0.04	0.06	
W.S. Elev (m)	107.5	Reach Len. (m)	19	19	19	
Crit W.S. (m)	106.68	Flow Area (m2)	27.42	45.26	14.87	
E.G. Slope (m/m)	0.002715	Area (m2)	27.42	45.26	28.54	101.22
Q Total (m3/s)	137.34	Flow (m3/s)	14.36	113.91	9.07	
Top Width (m)	90.46	Top Width (m)	37.95	16.34	36.17	
Vel Total (m/s)	1.57	Avg. Vel. (m/s)	0.52	2.52	0.61	
Max Chl Dpth (m)	3.38	Hydr. Depth (m)	0.73	2.77	0.57	1.12
Conv. Total (m3/s)	2635.7	Conv. (m3/s)	275.5	2186.1	174.1	
Length Wtd. (m)	19	Wetted Per. (m)	38.04	16.85	26.48	
Min Ch El (m)	104.12	Shear (N/m2)	19.19	71.51	14.95	
Alpha	2.16	Stream Power (N/m s)	5742.47	0	0	
Frctn Loss (m)		Cum Volume (1000 m:	1.12	24.51	0.85	
C & E Loss (m)		Cum SA (1000 m2)	5.75	11.5	1.58	

	Flow dis. (data)	*manual*	Overflow?	YES
Left WS Sta.		-46.79	-19.37	Flow through the bridge opening only
Left Eff. WS Sta.	-19.18	-15.73	-14.98	
Left Abutmnt Sta.	-10.29			
Right Abutmnt Sta.	10.29			
Right Eff. WS Sta.	29.18	15.97	10.96	
Right WS Sta.		33.46	12.74	

L' (left)	4.695	L (left)	9.081
L' (Right)	0.664	L (Right)	2.448

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT		12.6222	25.006			5.61	8.39
Main	20.5808	117.6474	50.7362	1.88	2.32	92.39	38.63
Right		7.0504	11.7878			0.48	0.74

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 50 Year

Overflow Separation. Elev. (est.) 106.912 Ave. Dept 0.588

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Reduced Q1, Qe	Reduced Area
1	LOB	-49.79	-46.6	0	0	0.19	0	0.01	0	0.34	0.00	0.00
2	LOB	-46.6	-43.17	0.23	1.02	3.47	0.17	0.3	0.23	7.86	0.00	0.00
3	LOB	-43.17	-39.75	0.66	1.9	3.43	0.48	0.56	0.35	14.78	0.00	0.00
4	LOB	-39.75	-36.32	0.87	2.25	3.43	0.63	0.66	0.39	17.48	0.08	0.23
5	LOB	-36.32	-32.9	0.8	2.14	3.43	0.58	0.63	0.37	16.63	0.06	0.13
6	LOB	-32.9	-29.47	0.52	1.66	3.43	0.38	0.48	0.32	12.9	0.00	0.00
7	LOB	-29.47	-26.05	0.28	1.15	3.43	0.21	0.34	0.25	8.92	0.00	0.00
8	LOB	-26.05	-22.62	0.1	0.61	3.43	0.07	0.18	0.16	4.74	0.00	0.00
9	LOB	-22.62	-19.18	0.23	1.02	3.51	0.17	0.3	0.23	7.77	0.00	0.00
10	LOB	-19.18	-15.73	2.28	4.09	3.59	1.66	1.19	0.56	30.3	1.14	2.06
11	LOB	-15.73	-12.29	4.28	5.86	3.45	3.11	1.7	0.73	45.24	2.80	3.84
12	LOB	-12.29	-8.84	4.09	5.7	3.45	2.98	1.66	0.72	44.08	2.63	3.67
13	Chan	-8.84	-7.21	5.94	3.12	1.71	4.32	1.91	1.9	48.64	4.12	2.16
14	Chan	-7.21	-5.57	8.01	3.76	1.74	5.83	2.3	2.13	57.62	5.96	2.80
15	Chan	-5.57	-3.94	12.12	4.8	1.71	8.82	2.94	2.53	74.55	9.70	3.84
16	Chan	-3.94	-2.3	14.14	5.18	1.64	10.29	3.17	2.73	83.83	11.51	4.22
17	Chan	-2.3	-0.67	15.54	5.48	1.64	11.32	3.35	2.84	88.81	12.82	4.52
18	Chan	-0.67	0.96	15.52	5.47	1.64	11.3	3.35	2.84	88.83	12.80	4.51
19	Chan	0.96	2.6	14.36	5.22	1.64	10.46	3.2	2.75	84.69	11.71	4.26
20	Chan	2.6	4.23	12.5	4.84	1.67	9.1	2.96	2.58	77.17	10.03	3.88
21	Chan	4.23	5.87	9.55	4.15	1.71	6.96	2.54	2.3	64.77	7.33	3.19
22	Chan	5.87	7.5	6.23	3.24	1.74	4.53	1.98	1.92	49.45	4.39	2.28
23	ROB	7.5	11.73	3.06	4.67	4.36	2.23	1.1	0.66	28.49	1.42	2.18
24	ROB	11.73	15.97	0.94	2.28	4.25	0.69	0.54	0.41	14.27	0.00	0.00
25	ROB	15.97	22.14	1.67	2.92	6.3	1.22	0.47	0.57	12.36	0.00	0.00
26	ROB	22.14	28.3	2.23	2.92	6.19	1.62	0.47	0.76	12.58	0.00	0.00
27	ROB	28.3	34.47	1.17	2.08	5.39	0.85	0.4	0.56	10.28	0.00	0.00
28	ROB	34.47	38.34							0	0	0
29	ROB	38.34	43.4	0	0.05	2.57	0	0.02	0	0.48	0	0
30	ROB	43.4	48.47	0	0.31	5.07	0	0.06	0	1.62	0	0
31	ROB	48.47	53.53	0	0.19	2.59	0	0.08	0	2	0	0
32											**98.49**	

Q Bridge
98.47

	Left	Right
Computed L' = Q_e/q_{tube} =	***4.695***	***0.664***
Q_e:	5.61	0.48
V_{tube}:	0.72	0.66
y_{tube}:	1.66	1.1
q_{tube}:	1.1952	0.726

BRIDGE SECTION

River Station 1288.5 BR U

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computati*** Yes

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 50 Year

E.G. Elev (m)	107.77	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.32	Wt. n-Val.				
W.S. Elev (m)	107.5	Reach Len. (m)	3.5	3.5	3.5	
Crit W.S. (m)	106.38	Flow Area (m2)	8.78	39.41	19.34	
E.G. Slope (m/m)		Area (m2)	5.55	39.41	13.97	58.93
Q Total (m3/s)	137.34	Flow (m3/s)	10.95	98.47	23.67	
Top Width (m)	47.93	Top Width (m)	11.65		36.27	
Vel Total (m/s)	2.03	Avg. Vel. (m/s)	1.25	2.5	1.22	
Max Chl Dpth (m)	3.54	Hydr. Depth (m)	0.75		0.7	1.23
Conv. Total (m3/s)		Conv. (m3/s)				
Length Wtd. (m)	3.5	Wetted Per. (m)	12.2	43.07	27.87	
Min Ch El (m)	103.96	Shear (N/m2)				
Alpha	1.08	Stream Power (N/m s)	3816.83	0	0	
Frctn Loss (m)		Cum Volume (1000 m3	0.81	23.7	0.44	
C & E Loss (m)		Cum SA (1000 m2)	5.28	11.34	0.9	

		Flow dis.	*manual*	Overflow?	YES
Left WS Sta.			-10.3	-10.3	Flow through the bridge opening only
Left Eff. WS Sta.				0	
Left Abutmnt Sta.		-10.3			
Right Abutmnt Sta.		10.3			
Right Eff. WS Sta.				0	
Right WS Sta.			10.3	10.3	
L' (left)	-10.3	L (left)	0		
L' (Right)	-10.3	L (Right)	0		

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT							
Main	20.6	98.49	39.41	1.91	2.50	98.49	39.41
Right							

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 50 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 107.5	Ave. Dept 0
1	Chan	-10.3	-8.84	2.98	1.96	4.18	3.02	1.34	1.52	0	0	2.98	1.96
2	Chan	-8.84	-6.71	7.33	3.4	4.29	7.44	1.6	2.15	0	0	7.33	3.40
3	Chan	-6.71	-4.59	11.8	4.54	4.31	11.98	2.13	2.6	0	0	11.80	4.54
4	Chan	-4.59	-2.46	15.01	5.22	4.27	15.24	2.45	2.88	0	0	15.01	5.22
5	Chan	-2.46	-0.33	17.81	5.78	4.26	18.08	2.72	3.08	0	0	17.81	5.78
6	Chan	-0.33	1.79	16.94	5.61	4.26	17.2	2.64	3.02	0	0	16.94	5.61
7	Chan	1.79	3.92	14.35	5.08	4.27	14.57	2.39	2.82	0	0	14.35	5.08
8	Chan	3.92	6.05	9.24	3.93	4.36	9.38	1.85	2.35	0	0	9.24	3.93
9	Chan	6.05	8.17	2.31	2.58	4.31	2.35	1.22	0.89	0	0	2.31	2.58
10	Chan	8.17	10.3	0.72	1.31	4.55	0.73	0.62	0.55	0	0	0.72	1.31
11												**98.49**	
12												Q Bridge	
13												98.47	
14													
15													
16													
17													
18													
19													
20													

BRIDGE OUTPUT

River Station 1288.5

Low Chord Elev.	106.54
Mean Channelbed Elev.	104.63
Bridge Opening Width	20.6

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 Profile: 50 Year

E.G. US. (m)	107.8	Element	Inside BR US	Inside BR DS
W.S. US. (m)	107.5	E.G. Elev (m)	107.77	107.73
Q Total (m3/s)	137.34	W.S. Elev (m)	107.5	107.5
Q Bridge (m3/s)	98.47	Crit W.S. (m)	106.38	106.38
Q Weir (m3/s)	36.35	Max Chl Dpth (m)	3.54	3.54
Weir Sta Lft (m)	-23.09	Vel Total (m/s)	2.03	2.05
Weir Sta Rgt (m)	38.34	Flow Area (m2)	67.53	66.99
Weir Submerg	0.35	Froude # Chl	0.42	0.42
Weir Max Depth (m	0.83	Specif Force (m3)	114.44	113.75
Min El Weir Flow (n	106.97	Hydr Depth (m)	1.73	1.67
Min El Prs (m)	106.74	W.P. Total (m)	83.14	84.28
Delta EG (m)	0.34	Conv. Total (m3/s)		
Delta WS (m)	0.2	Top Width (m)	47.93	45.13
BR Open Area (m2	39.41	Frctn Loss (m)		
BR Open Vel (m/s)	2.5	C & E Loss (m)		
Coef of Q		Shear Total (N/m2)		
Br Sel Method	Press/Weir	Power Total (N/m s)	-1599.12	-1549.33

eight of Vertical Exposed Face of Abutment	0.75	
Approx. Side Slope of channel below bridge	4	:1 (h:v)
Approx. channel bottpm width	6.40	
Hydraulic depth to mean bed elevation	2.52	
Hydraulic depth	1.91	

PRESSURE FLOW SCOUR

Live-Bed Vertical Contraction Scour ==========

$Y_s/Y_1 = -5.08 + 1.27 (Y_1 / H_b) + 4.44 (H_b / Y_1) + 0.19 (V_a / V_c) =$ **0.02 m** .....Eq. 6.21 (Arneson's Eq.)

Y_s =	**0.05 m**	Depth of vertical contraction scour relative to mean bed elevation
Y_1 =	2.87 m	Depth of flow immediately upstream of the bridge (hydraulic depth at upstream face)
H_b =	1.91 m	Distance from the low chord of the bridge to the average elevation of the stream bed before scour
V_a =	2.5 m/s	Average velocity of the flow through the bridge opening before scour occurs
V_c =	2.03 m/s	Critical velocity of the D_{50} of the bed material in the bridge opening
	D_{50} = (Design)	m if different from the value used in the Contraction Scour computation

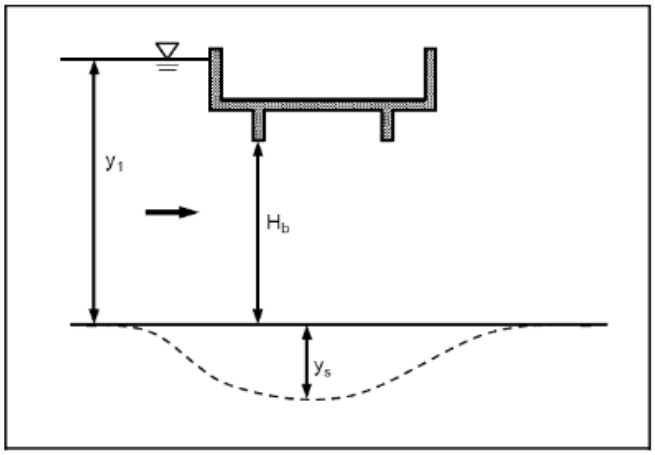
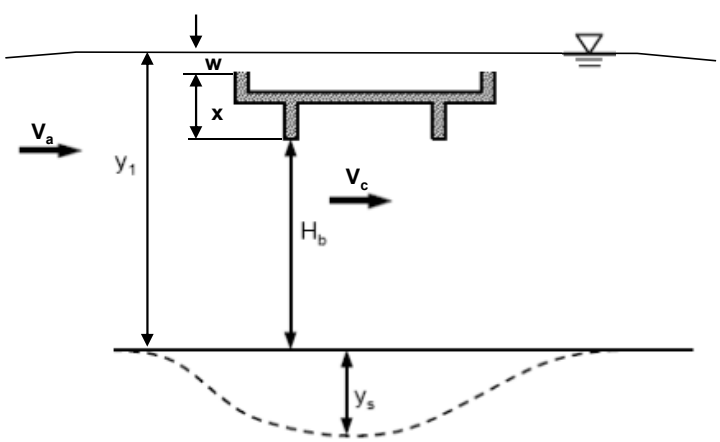


Figure 6.14. Definition sketch of vertical contraction scour resulting from pressure flow.

Clear-Water Contraction Scour ==========

$H_b + Y_s/Y_a = 1.1021 [(1 - w / Y_a) V_a / V_c]^{0.6031} =$ **0.74 m** .....HEC-18 (1995) App. B (Umbrell)

Y_s =	**0.00 m**	Depth of vertical scour **LIVE-BED controls. Ignore this procedure**
Y_a =	2.87 m	Depth of flow immediately upstream of the bridge (approch depth)
H_b =	1.91 m	Depth from the low chord of the bridge to original river bed
V_a =	1.57 m/s	Approach Velocity
V_c =	2.50 m/s	Velocity under the bridge deck. (V_c is equal to the incipient motion velocity)
w =	0.53 m	Depth of overflow



PROJECT NO. 151-273 **BRIDGE NO.** Pedestrian Crossing **UNIT:** Metric

Ref. HEC-18., May 2001 (4th ed.)

(October 2013 Note: These equation are still valid in HEC-18, 5th ed.)

SUMMARY

Contraction Scour		Type:	LIVE-BED	Depth:	0.03 m	Event:	100-YR
Local	East Abut. #2	LEFT	Eq.: Froehlich	Depth:	1.49 m	Event:	100-YR
Abutment	West Abut. #1	RIGHT	Eq.: Froehlich	Depth:	0.46 m	Event:	100-YR

CONTRACTION SCOUR

$V_c = K_u y^{1/6} D^{1/3}$ .....Eq. 5.1

= 2.01 *m/s* Critacal velocity above which bed material of size D and smaller will be transported

Ku = 6.19 m (6.19 in SI units; 11.17 in English units)

y = 2.06 m Average depth of flow upstream of the bridge

D = 0.024 m Particle size for Vc , *m* (use D_{50})

V = 2.39 *m/s* The mean velocity of the flow in the main channel or overbank area upstream of the brige opening

Vc < V ***Thus, LIVE-BED CONTRACTION SCOUR***

Live-Bed Contraction Scour ==========

$Y_2/Y_1 = (Q_2/Q_1)^{6/7} (W_1/W_2)^{k_1}$ = 0.94 .....Eq. 5.2

$Y_s = Y_2 - Y_o$ m .....Eq. 5.3

= 0.03 m Average contraction scour depth

Y_1 = 2.06 m Average depth in the upstream main channel

Y_2 = 1.95 m Average depth in the contracted section

Y_o = 1.91 m Existing depth in the contracted section before scour

Q_1 = 85.86 m3/s Flow in the upstream channel transporting sediment

Q_2 = 94.16 m3/s Flow in the contracted channel

W_1 = 16.34 m Bottom width of the upstream main channel that is transporting bed material

W_2 = 20.60 m Bottom width of the main channel in the contracted section less pier width

k_1 = 0.59 Exponent determined below (V^*/ω = 0.42)

V^* = 0.2617 $=(T_o/\rho)^{1/2}$ or $(gY1\ S1)^{1/2}$, shear velocity in the upstream section , m/s

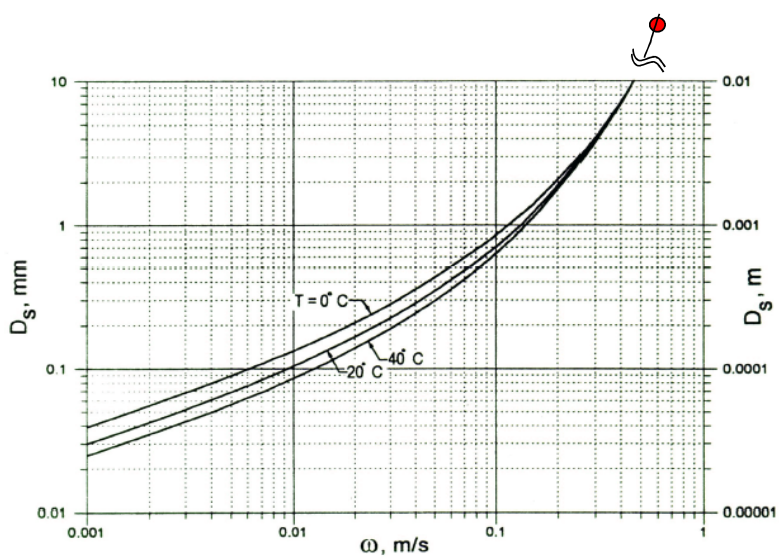
ω = 0.63 m/s Fall velocity of bed material based on the D_{50} (Figure 5.8)

g = 9.81 m/s^2 Acceleration of gravity

S1 = 0.002279 m/m Slope of energy gradeline of main channel

T_o = 68.48 Pa (N/m^2) Shear stess on the bed

ρ = 1000 kg/m^3 Density of water



V^*/ω	k1	*Mode of Bed Material Transport*
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

Figure 5.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Clear-Water Contraction Scour ==========

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2}\right]^{3/7}$$ .....Eq. 5.4

$$y_s = y_2 - y_o$$ m .....Eq. 5.5

=	N/A	m	Average contraction scour depth **LIVE-BED controls. Ignore this procedure**
y_2 =	2.06	m	Average equilibrium depth in the contracted section after contraction scour
y_o =	1.91	m	Average existing depth in the contracted section
Q =	94.16	m3/s	Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W
W =	20.60	m	Bottom width of the contracted section less pier widths
K_u =	0.0250		(0.025 in SI units; 0.0077 in English units)
D_m =	0.0300	m	Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in th contacted setion
D_{50} =	0.0240	m	Median diameter of bed material

Because D_{50} is not the largest particle in the bed material, the scoured section can be slightly armored. Therefore, the D_m is assumed to be 1.25 D_{50}. For stratified bed material the depth of scour can be determined by using the clear-water scour equation sequentially with successive D_m of the bed material layers.

Data Source

Eq. 5.1			From:	RS
y =	2.06	m	D	1309
V =	2.39	m	D	1288.5 BR U

Eq. 5.2 & 5.3				
Y1 =	2.06	m	D	1309
Yo =	1.91	m	D	1288.5 BR U
Q1 =	85.864495	m3/s	D	1309
Q2 =	94.16	m3/s	D	1288.5 BR U
W1 =	16.34	m	D	1309
or (n/a)		m (manual)		
W2 =	20.6	m	D	1288.5 BR U
or (n/a)		m (manual)		
S1 =	0.002279	m/m	C	1309
To =	68.48	Pa (N/m^2)	C	1309
P2 =	0	m (pier width)		

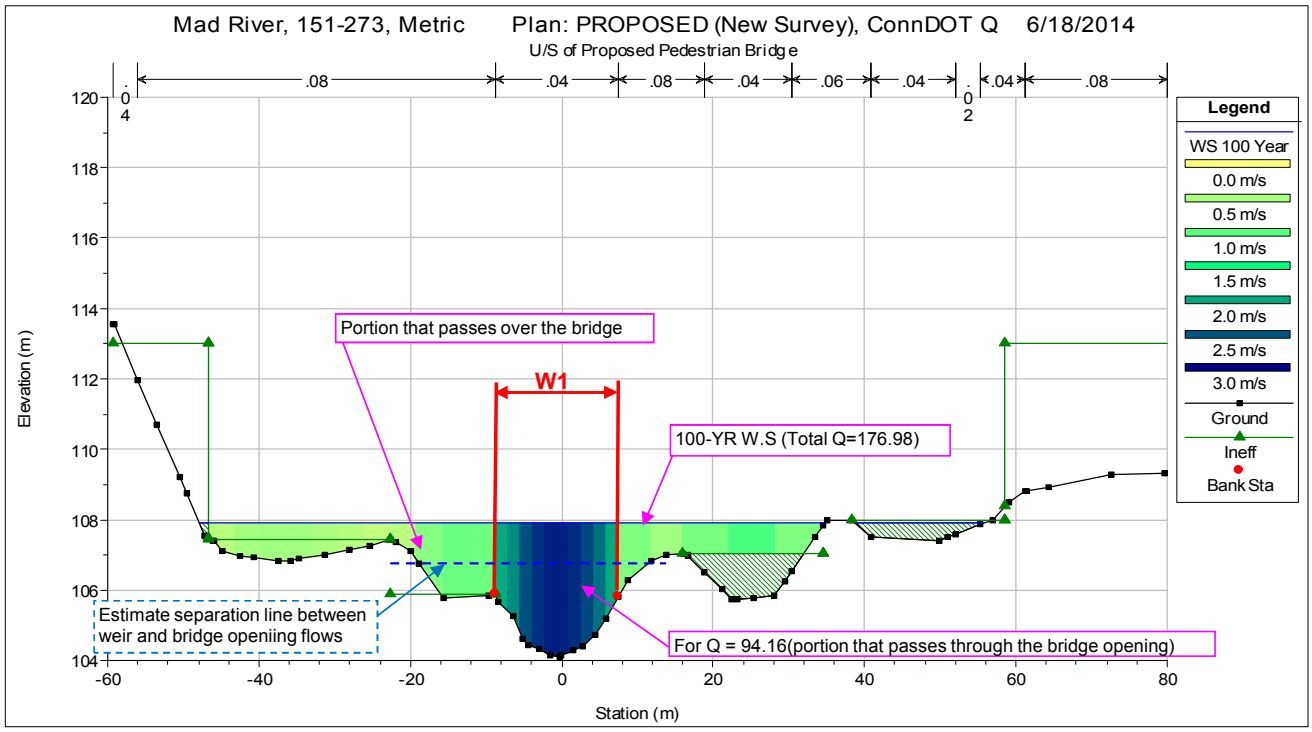
Eq. 5.4 & 5.5				
Q =	94.16	m3/s	C	1288.5
W =	20.6	m	C	1288.5
yo =	1.91	m	C	1288.5

Legends:

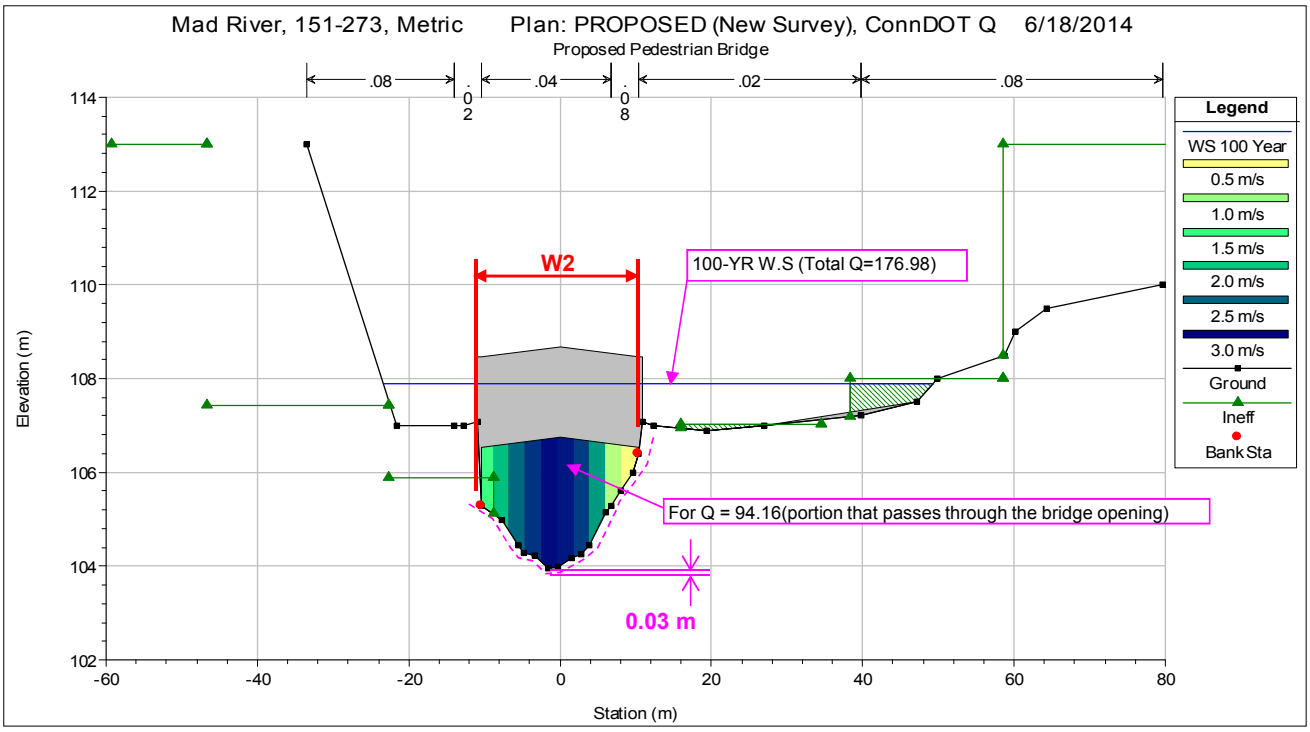
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections used for Contraction Scour Computations

UPSTREAM SECTION 1309



CONTRACTED SECTION 1288.5 BR U



*This drawing is intended to provide a basic, rough visualization of the scour depth. See Figure 5 for a more accurate depiction.

UPSTREAM CHANNEL SECTION

River Station 1309 Event: 100-YR

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computati*** No except channel stations

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 100 Year

		Element	Left OB	Channel	Right OB	Total
E.G. Elev (m)	108.2					
Vel Head (m)	0.24	Wt. n-Val.	0.08	0.04	0.058	
W.S. Elev (m)	107.89	Reach Len. (m)	19	19	19	
Crit W.S. (m)	107	Flow Area (m2)	42.13	51.62	25.23	
E.G. Slope (m/m)	0.002279	Area (m2)	42.45	51.62	44.18	138.25
Q Total (m3/s)	176.98	Flow (m3/s)	26.91	129.97	20.09	
Top Width (m)	99.38	Top Width (m)	38.98	16.34	44.05	
Vel Total (m/s)	1.49	Avg. Vel. (m/s)	0.64	2.52	0.8	
Max Chl Dpth (m)	3.77	Hydr. Depth (m)	1.12	3.16	0.93	1.39
Conv. Total (m3/s)	3707	Conv. (m3/s)	563.7	2722.4	420.8	
Length Wtd. (m)	19	Wetted Per. (m)	38.04	16.85	27.81	
Min Ch El (m)	104.12	Shear (N/m2)	24.76	68.48	20.28	
Alpha	2.16	Stream Power (N/m s)	5742.47	0	0	
Frctn Loss (m)		Cum Volume (1000 m3)	4.13	28.68	1.55	
C & E Loss (m)		Cum SA (1000 m2)	14.95	11.77	2.47	

		Flow dis.	*manual*		
		(data)		Overflow?	YES
Left WS Sta.			-47.82	-19.05	Flow through the bridge opening only
Left Flood Sta.				-19.05	
Left Main Channel		-8.84			
Right Main Channel		7.5			
Right Flood Sta.				11.69	
Right WS Sta.			34.72	11.69	
L' (left)	10.21	L (left)	10.21		
L' (Right)	4.19	L (Right)	4.19		

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT		26.92	42.46			7.03	8.36
Main	16.34	129.97	51.61	2.06	2.52	85.86	33.72
Right		20.09	25.25			1.28	1.69

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 100 Year

Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 106.795	Ave. Dept 1.095
1 LOB	-49.79	-46.6	0	0.32	1.31	0	0.26	0	5.47	0	0.00	0.00
2 LOB	-46.6	-43.17	0.98	2.36	3.47	0.55	0.69	0.41	15.21	6.29	0.00	0.00
3 LOB	-43.17	-39.75	1.67	3.24	3.43	0.94	0.95	0.51	21.11	10.87	0.00	0.00
4 LOB	-39.75	-36.32	1.98	3.58	3.43	1.12	1.05	0.55	23.38	12.89	0.00	0.00
5 LOB	-36.32	-32.9	1.88	3.48	3.43	1.06	1.01	0.54	22.66	12.24	0.00	0.00
6 LOB	-32.9	-29.47	1.46	3	3.43	0.83	0.87	0.49	19.53	9.55	0.00	0.00
7 LOB	-29.47	-26.05	1.07	2.48	3.43	0.61	0.72	0.43	16.19	6.99	0.00	0.00
8 LOB	-26.05	-22.62	0.71	1.95	3.43	0.4	0.57	0.37	12.67	4.64	0.00	0.00
9 LOB	-22.62	-19.18	0.97	2.37	3.51	0.55	0.69	0.41	15.06	6.19	0.00	0.00
10 LOB	-19.18	-15.73	3.83	5.43	3.59	2.16	1.58	0.7	33.78	23.8	1.19	1.65
11 LOB	-15.73	-12.29	6.3	7.2	3.45	3.56	2.09	0.87	46.67	40.79	3.02	3.43
12 LOB	-12.29	-8.84	6.07	7.05	3.45	3.43	2.05	0.86	45.71	39.4	2.82	3.27
13 Chan	-8.84	-7.21	7.45	3.76	1.71	4.21	2.3	1.98	49.16	97.35	3.92	1.98
14 Chan	-7.21	-5.57	9.57	4.4	1.74	5.41	2.69	2.17	56.55	122.94	5.67	2.60
15 Chan	-5.57	-3.94	13.74	5.43	1.71	7.76	3.33	2.53	70.89	179.18	9.22	3.65
16 Chan	-3.94	-2.3	15.8	5.81	1.64	8.93	3.56	2.72	79.03	214.79	10.92	4.01
17 Chan	-2.3	-0.67	17.19	6.11	1.64	9.71	3.74	2.81	83.22	234.09	12.17	4.33
18 Chan	-0.67	0.96	17.17	6.1	1.64	9.7	3.74	2.81	83.25	234.24	12.15	4.32
19 Chan	0.96	2.6	16.02	5.86	1.64	9.05	3.59	2.73	79.76	218.11	11.12	4.06
20 Chan	2.6	4.23	14.14	5.47	1.67	7.99	3.35	2.58	73.31	189.5	9.54	3.69
21 Chan	4.23	5.87	11.16	4.79	1.71	6.3	2.93	2.33	62.71	146.07	6.98	2.99
22 Chan	5.87	7.5	7.73	3.88	1.74	4.37	2.37	1.99	49.67	99.04	4.18	2.10
23 ROB	7.5	11.73	4.75	6.32	4.36	2.68	1.49	0.75	32.38	24.35	1.28	1.69
24 ROB	11.73	15.97	2.19	3.93	4.25	1.24	0.93	0.56	20.67	11.52	0.00	0.00
25 ROB	15.97	22.14	4.25	5.33	6.3	2.4	0.86	0.8	18.9	15.08	0.00	0.00
26 ROB	22.14	28.3	5.66	5.33	6.19	3.2	0.86	1.06	19.25	20.47	0.00	0.00
27 ROB	28.3	34.47	3.24	4.33	6.45	1.83	0.7	0.75	14.99	11.22	0.00	0.00
28 ROB	34.47	38.34	0	0.01	0.26	0	0.04	0.09	0.81	0.07	0.00	0.00
29 ROB	38.34	43.4	0	1.44	4.6	0	0.31	0	6.98	0	0	0
30 ROB	43.4	48.47	0	2.28	5.07	0	0.45	0	10.07	0	0	0
31 ROB	48.47	53.53	0	1.91	5.08	0	0.38	0	8.43	0	0	0
32 ROB	53.53	58.6	0	0.19	2.15	0	0.09	0	2.03	0	0	0
33											**94.17**	
34											Q Bridge	
35											94.16	
36												
37												
38												
39												
40												
41												
42												
43												
44												
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46												
47												
48												
49												
50												

CONTRACTED CHANNEL SECTION

River Station 1288.5 BR U

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 100 Year

E.G. Elev (m)	108.14	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.42	Wt. n-Val.				
W.S. Elev (m)	107.89	Reach Len. (m)	3.5	3.5	3.5	
Crit W.S. (m)	106.57	Flow Area (m2)	13.33	39.41	37.11	
E.G. Slope (m/m)		Area (m2)	10.24	39.41	28.51	78.16
Q Total (m3/s)	176.98	Flow (m3/s)	20.01	94.16	53.32	
Top Width (m)	50.8	Top Width (m)	12.42		38.38	
Vel Total (m/s)	1.97	Avg. Vel. (m/s)	1.5	2.39	1.44	
Max Chl Dpth (m)	3.93	Hydr. Depth (m)	1.07		1.35	1.54
Conv. Total (m3/s)		Conv. (m3/s)				
Length Wtd. (m)	3.5	Wetted Per. (m)	13.45	43.07	28.26	
Min Ch El (m)	103.96	Shear (N/m2)				
Alpha	1.36	Stream Power (N/m s)	3816.83	0	0	
Frctn Loss (m)		Cum Volume (1000 m3)	3.62	27.81	0.86	
C & E Loss (m)		Cum SA (1000 m2)	14.47	11.61	1.69	

		Flow dis.	*manual*
Left WS Sta.			-10.3
Left Flood Sta.			
Left Main Channel		-10.3	
Right Main Channel		10.3	
Right Flood Sta.			
Right WS Sta.			10.3
L' (left)	-10.3	L (left)	0
L' (Right)	-10.3	L (Right)	0

Overflow?	YES
	8.17
	8.17
	0
	0

Flow through the bridge opening only

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT							
Main	20.6	94.16	39.41	1.91	2.39	94.16	39.41
Right							

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 100 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 107.89	Ave. Dept 0
1	Chan	-10.3	-8.84	2.85	1.96	4.18	3.02	1.34	1.45	0	0	2.85	1.96
2	Chan	-8.84	-6.71	7	3.4	4.29	7.44	1.6	2.06	0	0	7.00	3.40
3	Chan	-6.71	-4.59	11.28	4.54	4.31	11.98	2.13	2.49	0	0	11.28	4.54
4	Chan	-4.59	-2.46	14.35	5.22	4.27	15.24	2.45	2.75	0	0	14.35	5.22
5	Chan	-2.46	-0.33	17.03	5.78	4.26	18.08	2.72	2.95	0	0	17.03	5.78
6	Chan	-0.33	1.79	16.2	5.61	4.26	17.2	2.64	2.89	0	0	16.20	5.61
7	Chan	1.79	3.92	13.72	5.08	4.27	14.57	2.39	2.7	0	0	13.72	5.08
8	Chan	3.92	6.05	8.83	3.93	4.36	9.38	1.85	2.25	0	0	8.83	3.93
9	Chan	6.05	8.17	2.21	2.58	4.31	2.35	1.22	0.86	0	0	2.21	2.58
10	Chan	8.17	10.3	0.69	1.31	4.55	0.73	0.62	0.53	0	0	0.69	1.31
11												**94.16**	
12												Q Bridge	
13												94.16	

LIVE SCOUR AT ABUTMENTS

Froehlich's Live-Bed Abutment Scour Equation — *LEFT* — *RIGHT* — ==========

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 1 =$ — **2.82** — **2.06** — .....Eq. 7.1

Amended Local Scour Equation

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 0.05 =$ — **1.87** — **1.11** — .....CT DOT DM Pg 9B-2

	LEFT	*RIGHT*		
Ys =	**1.49**	**0.46**	**m**	Scour depth <== using Amended equation
K_1 =	1.00	0.82		Coeffcient for abutment shape (see Table 7.1 and Figrue 7.6)
K_2 =	0.91	1.06		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
θ =	43	138		
				θ < 90 degrees if embankment points downstream
				θ > 90 degrees if embankment points upstream
				(see Figure 7.5 for definition of θ)
L' =	3.32	0.39	m	Length of active flow obstructed by the embankment (see Figure 7.4)
Ae =	6.98	0.57	m^2	Flow area of the approach cross section obstructed by the embankment
Fr =	0.30	0.38		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment
Ve =	0.84	0.76	m/s	Qe/Ae
Qe =	5.844717	0.433878	m^3/s	Flow obstructed by the abutment and approach embankment
Ya =	0.80	0.41	m	Ae/L, Average depth of flow on the floodplain
L =	8.761	1.3982	m	Length of embankment projected normal to the flow

Table 7.1. Abutment Shape Coefficients.

Description	K_1
Vertical-wall abutment	1.00
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

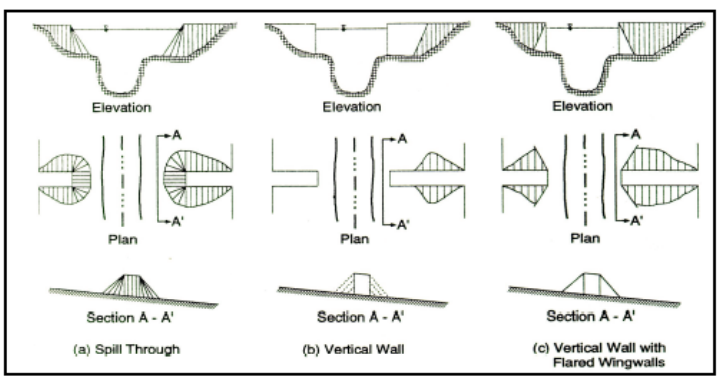


Figure 7.6. Abutment shape.

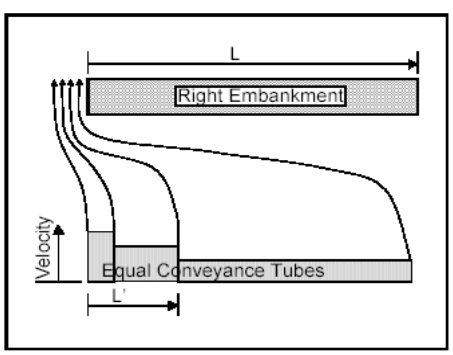


Figure 7.4. Determination of length of embankment blocking live flow for abutment scour estimation.

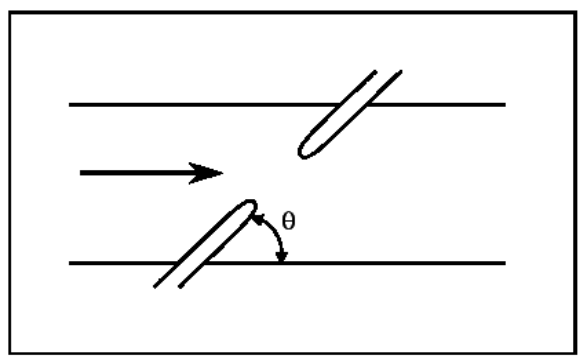


Figure 7.5. Orientation of embankment angle, θ, to the flow.

HIRE Live-Bed Abutment Scour Equation ==========

		LEFT	RIGHT	
Applicability check:	L/Y_1 =	4	1	*Use HIRE Eq. only if $L/Y_1 > 25$*
$Y_s/Y_1 = 4\ Fr^{0.33}\ K_1/0.55\ K_2$ =		**N/A**	**N/A**	.....Eq. 7.1

	LEFT	RIGHT		
Y_s =	**N/A**	**N/A**	**m**	Scour depth (N/A if $L/Y_1 < 25$)
K1 =	1.00	0.82		Coeffcient for abutment shape (see Table 7.1 on RIGHT)
K2 =	0.91	1.06		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
Y1 =	2.06	2.06	m	Depth of flow at the abutment on the overbank or in the main channel,
Fr =	0.30	0.38		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment

Data Source

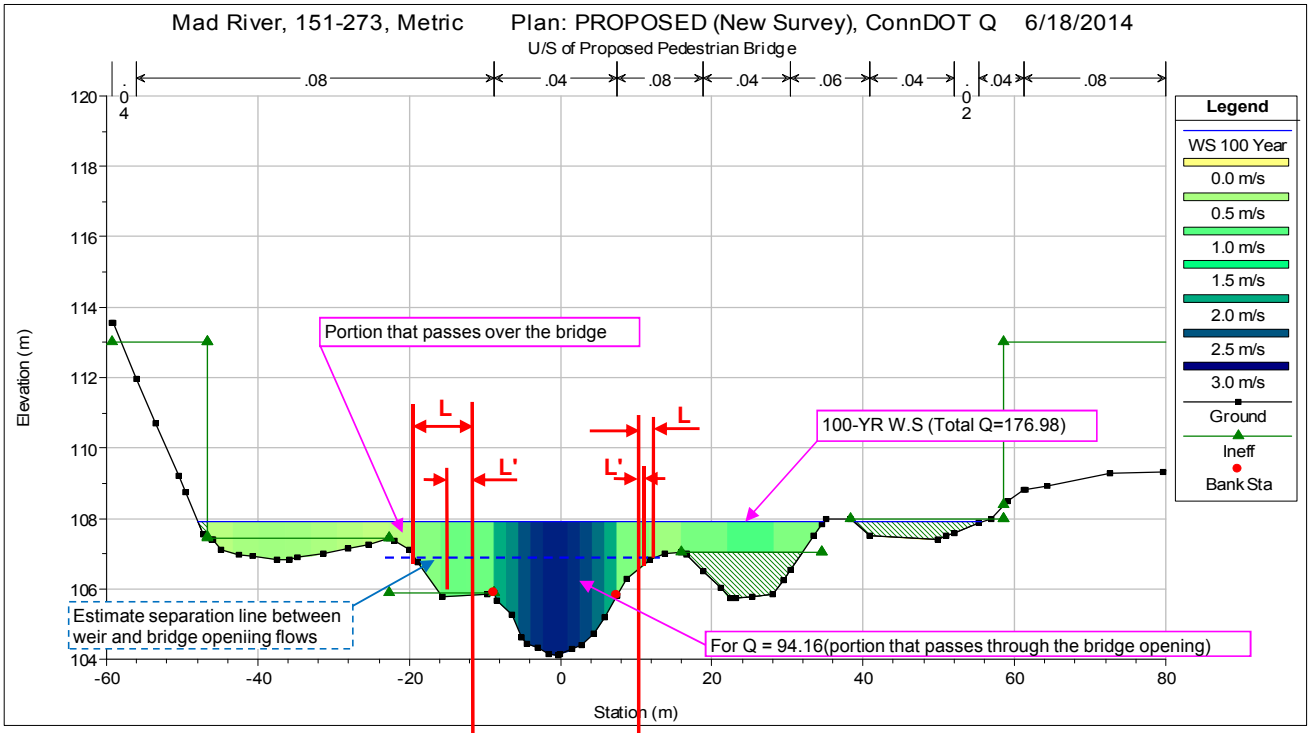
Eq. 7.1				From:	RS
	LT			UC	
		L' =	3.3152 m	D	1309
		Ae =	6.9834 m2	D	1309
		Qe =	5.8447 m3/s	D	1309
		L =	8.761 m	D	1309
	RT			UC	
		L' =	0.3883 m	D	1309
		Ae =	0.574 m2	D	1309
		Qe =	0.4339 m3/s	D	1309
		L =	1.3982 m	D	1309

Legends:

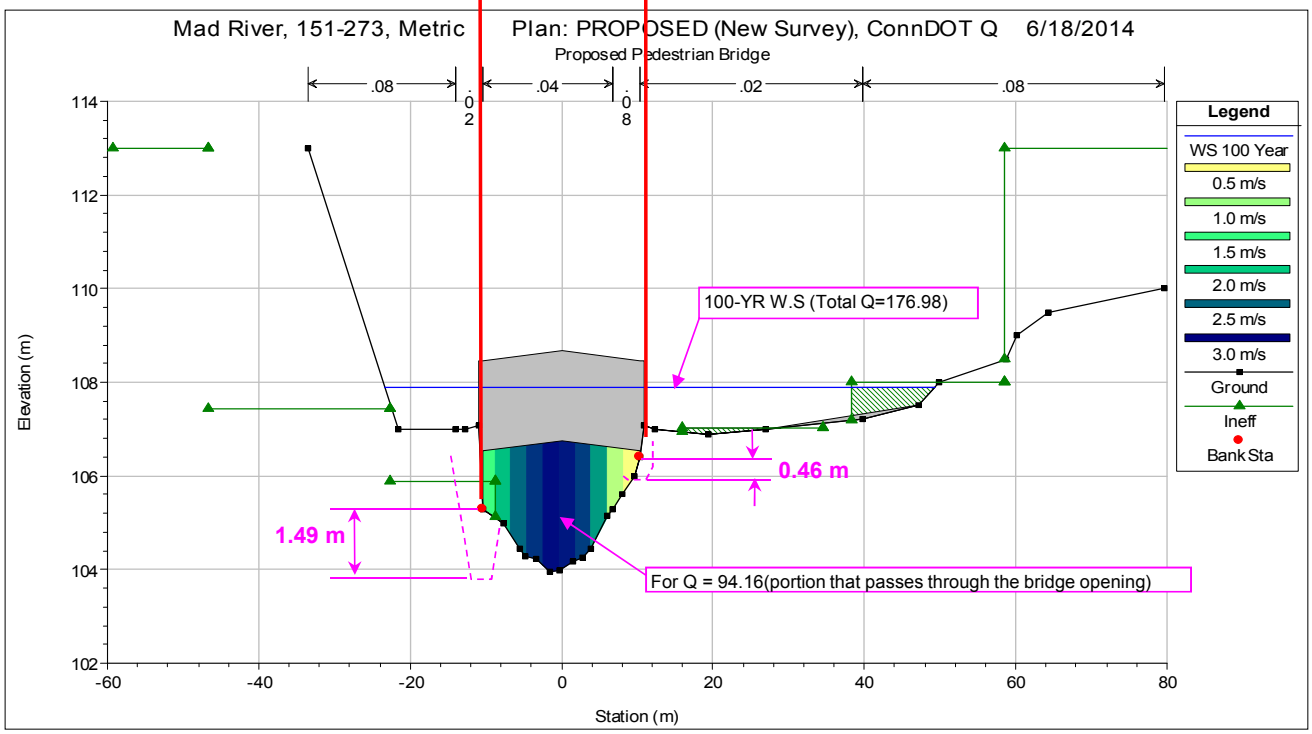
UC	from an upstream Cross Section output (approach section)
UF	from Bridge Upstream Face - Cross Section output (BR U); or Bridge Downstream Face (BR D) - this is seldom used
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections Used for Local Abutment Scour Computations

APPROACH SECTION 1309



1288.5 BR U **1288.5 BR U**



** This drawing is intended to provide a basic, rough visualization of the scour depth. See Figure 5 for a more accurate depiction of combined total scour*

UPSTREAM APPROACH CHANNEL SECTION

River Station 1309 Event: 100-YR

CROSS SECTION OUTPUT *Use the same data as in the contraction scour computatio* YES except channel stations

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 100 Year

E.G. Elev (m)	108.2	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.24	Wt. n-Val.	0.08	0.04	0.058	
W.S. Elev (m)	107.89	Reach Len. (m)	19	19	19	
Crit W.S. (m)	107	Flow Area (m2)	42.13	51.62	25.23	
E.G. Slope (m/m)	0.002279	Area (m2)	42.45	51.62	44.18	138.25
Q Total (m3/s)	176.98	Flow (m3/s)	26.91	129.97	20.09	
Top Width (m)	99.38	Top Width (m)	38.98	16.34	44.05	
Vel Total (m/s)	1.49	Avg. Vel. (m/s)	0.64	2.52	0.8	
Max Chl Dpth (m)	3.77	Hydr. Depth (m)	1.12	3.16	0.93	1.39
Conv. Total (m3/s)	3707	Conv. (m3/s)	563.7	2722.4	420.8	
Length Wtd. (m)	19	Wetted Per. (m)	38.04	16.85	27.81	
Min Ch El (m)	104.12	Shear (N/m2)	24.76	68.48	20.28	
Alpha	2.16	Stream Power (N/m s)	5742.47	0	0	
Frctn Loss (m)		Cum Volume (1000 m3	4.13	28.68	1.55	
C & E Loss (m)		Cum SA (1000 m2)	14.95	11.77	2.47	

	Flow dis.	*manual*	Overflow?	YES
Left WS Sta.	(data)	-47.82	-19.05	Flow through the bridge opening only
Left Eff. WS Sta.	-19.18	-15.73	-13.60	
Left Abutmnt Sta.	-10.29			
Right Abutmnt Sta.	10.29			
Right Eff. WS Sta.	29.18	15.97	10.68	
Right WS Sta.		34.72	11.69	
L' (left) 3.315	L (left)	8.761		
L' (Right) 0.388	L (Right)	1.398		

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT		24.3706	39.499			5.84	6.98
Main	20.5808	135.6544	58.7422	1.76	2.31	87.89	36.21
Right		16.955	21.0788			0.43	0.57

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 100 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 106.795	Ave. Dept 1.095
1	LOB	-49.79	-46.6	0	0.32	1.31	0	0.26	0	5.47	0	0.00	0.00
2	LOB	-46.6	-43.17	0.98	2.36	3.47	0.55	0.69	0.41	15.21	6.29	0.00	0.00
3	LOB	-43.17	-39.75	1.67	3.24	3.43	0.94	0.95	0.51	21.11	10.87	0.00	0.00
4	LOB	-39.75	-36.32	1.98	3.58	3.43	1.12	1.05	0.55	23.38	12.89	0.00	0.00
5	LOB	-36.32	-32.9	1.88	3.48	3.43	1.06	1.01	0.54	22.66	12.24	0.00	0.00
6	LOB	-32.9	-29.47	1.46	3	3.43	0.83	0.87	0.49	19.53	9.55	0.00	0.00
7	LOB	-29.47	-26.05	1.07	2.48	3.43	0.61	0.72	0.43	16.19	6.99	0.00	0.00
8	LOB	-26.05	-22.62	0.71	1.95	3.43	0.4	0.57	0.37	12.67	4.64	0.00	0.00
9	LOB	-22.62	-19.18	0.97	2.37	3.51	0.55	0.69	0.41	15.06	6.19	0.00	0.00
10	LOB	-19.18	-15.73	3.83	5.43	3.59	2.16	1.58	0.7	33.78	23.8	1.19	1.65
11	LOB	-15.73	-12.29	6.3	7.2	3.45	3.56	2.09	0.87	46.67	40.79	3.02	3.43
12	LOB	-12.29	-8.84	6.07	7.05	3.45	3.43	2.05	0.86	45.71	39.4	2.82	3.27
13	Chan	-8.84	-7.21	7.45	3.76	1.71	4.21	2.3	1.98	49.16	97.35	3.92	1.98
14	Chan	-7.21	-5.57	9.57	4.4	1.74	5.41	2.69	2.17	56.55	122.94	5.67	2.60
15	Chan	-5.57	-3.94	13.74	5.43	1.71	7.76	3.33	2.53	70.89	179.18	9.22	3.65
16	Chan	-3.94	-2.3	15.8	5.81	1.64	8.93	3.56	2.72	79.03	214.79	10.92	4.01
17	Chan	-2.3	-0.67	17.19	6.11	1.64	9.71	3.74	2.81	83.22	234.09	12.17	4.33
18	Chan	-0.67	0.96	17.17	6.1	1.64	9.7	3.74	2.81	83.25	234.24	12.15	4.32
19	Chan	0.96	2.6	16.02	5.86	1.64	9.05	3.59	2.73	79.76	218.11	11.12	4.06
20	Chan	2.6	4.23	14.14	5.47	1.67	7.99	3.35	2.58	73.31	189.5	9.54	3.69
21	Chan	4.23	5.87	11.16	4.79	1.71	6.3	2.93	2.33	62.71	146.07	6.98	2.99
22	Chan	5.87	7.5	7.73	3.88	1.74	4.37	2.37	1.99	49.67	99.04	4.18	2.10
23	ROB	7.5	11.73	4.75	6.32	4.36	2.68	1.49	0.75	32.38	24.35	1.28	1.69
24	ROB	11.73	15.97	2.19	3.93	4.25	1.24	0.93	0.56	20.67	11.52	0.00	0.00
25	ROB	15.97	22.14	4.25	5.33	6.3	2.4	0.86	0.8	18.9	15.08	0.00	0.00
26	ROB	22.14	28.3	5.66	5.33	6.19	3.2	0.86	1.06	19.25	20.47	0.00	0.00
27	ROB	28.3	34.47	3.24	4.33	6.45	1.83	0.7	0.75	14.99	11.22	0.00	0.00
28	ROB	34.47	38.34	0	0.01	0.26	0	0.04	0.09	0.81	0.07	0.00	0.00
29	ROB	38.34	43.4	0	1.44	4.6	0	0.31	0	6.98	0	0	0
30	ROB	43.4	48.47	0	2.28	5.07	0	0.45	0	10.07	0	0	0
31	ROB	48.47	53.53	0	1.91	5.08	0	0.38	0	8.43	0	0	0
32	ROB	53.53	58.6	0	0.19	2.15	0	0.09	0	2.03	0	0	0
33												**94.17**	
34												Q Bridge	
35												94.16	

	Left	Right
Computed L' = Q_e/q_{tube} =	***3.315***	***0.388***
Q_e:	5.84	0.43
V_{tube}:	0.86	0.75
y_{tube}:	2.05	1.49
q_{tube}:	1.763	1.1175

BRIDGE SECTION

River Station 1288.5 BR U

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computatio*** Yes

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 100 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	108.14	Element				
Vel Head (m)	0.42	Wt. n-Val.				
W.S. Elev (m)	107.89	Reach Len. (m)	3.5	3.5	3.5	
Crit W.S. (m)	106.57	Flow Area (m2)	13.33	39.41	37.11	
E.G. Slope (m/m)		Area (m2)	10.24	39.41	28.51	78.16
Q Total (m3/s)	176.98	Flow (m3/s)	20.01	94.16	53.32	
Top Width (m)	50.8	Top Width (m)	12.42		38.38	
Vel Total (m/s)	1.97	Avg. Vel. (m/s)	1.5	2.39	1.44	
Max Chl Dpth (m)	3.93	Hydr. Depth (m)	1.07		1.35	1.54
Conv. Total (m3/s)		Conv. (m3/s)				
Length Wtd. (m)	3.5	Wetted Per. (m)	13.45	43.07	28.26	
Min Ch El (m)	103.96	Shear (N/m2)				
Alpha	1.36	Stream Power (N/m s)	3816.83	0	0	
Frctn Loss (m)		Cum Volume (1000 m3	3.62	27.81	0.86	
C & E Loss (m)		Cum SA (1000 m2)	14.47	11.61	1.69	

		Flow dis.	*manual*	Overflow?	YES
Left WS Sta.			-10.3	-10.3	Flow through the bridge opening only
Left Eff. WS Sta.				0	
Left Abutmnt Sta.		-10.3			
Right Abutmnt Sta.		10.3			
Right Eff. WS Sta.				0	
Right WS Sta.			10.3	10.3	
L' (left)	-10.3	L (left)	0		
L' (Right)	-10.3	L (Right)	0		

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT							
Main	20.6	94.16	39.41	1.52	2.39	77.18	31.38
Right							

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 100 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 107.5	Ave. Dept 0.39
1	Chan	-10.3	-8.84	2.85	1.96	4.18	3.02	1.34	1.45	0	0	2.02	1.39
2	Chan	-8.84	-6.71	7	3.4	4.29	7.44	1.6	2.06	0	0	5.29	2.57
3	Chan	-6.71	-4.59	11.28	4.54	4.31	11.98	2.13	2.49	0	0	9.22	3.71
4	Chan	-4.59	-2.46	14.35	5.22	4.27	15.24	2.45	2.75	0	0	12.07	4.39
5	Chan	-2.46	-0.33	17.03	5.78	4.26	18.08	2.72	2.95	0	0	14.58	4.95
6	Chan	-0.33	1.79	16.2	5.61	4.26	17.2	2.64	2.89	0	0	13.81	4.78
7	Chan	1.79	3.92	13.72	5.08	4.27	14.57	2.39	2.7	0	0	11.48	4.25
8	Chan	3.92	6.05	8.83	3.93	4.36	9.38	1.85	2.25	0	0	6.96	3.10
9	Chan	6.05	8.17	2.21	2.58	4.31	2.35	1.22	0.86	0	0	1.50	1.75
10	Chan	8.17	10.3	0.69	1.31	4.55	0.73	0.62	0.53	0	0	0.25	0.48
11												**77.18**	
12												Q Bridge	
13												94.16	
14													
15													
16													
17													
18													
19													
20													

BRIDGE OUTPUT

River Station 1288.5

Low Chord Elev.	106.54
Mean Channelbed Elev.	104.63
Bridge Opening Width	20.6

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 Profile: 100 Year

			Inside BR US	Inside BR DS
E.G. US. (m)	108.2	Element		
W.S. US. (m)	107.89	E.G. Elev (m)	108.14	108.14
Q Total (m3/s)	176.98	W.S. Elev (m)	107.89	107.79
Q Bridge (m3/s)	94.16	Crit W.S. (m)	106.57	106.57
Q Weir (m3/s)	77	Max Chl Dpth (m)	3.93	3.83
Weir Sta Lft (m)	-23.8	Vel Total (m/s)	1.97	2.16
Weir Sta Rgt (m)	52.31	Flow Area (m2)	89.85	81.81
Weir Submerg	0.6	Froude # Chl	0.46	0.44
Weir Max Depth (m	1.19	Specif Force (m3)	154.02	145.32
Min El Weir Flow (m	106.97	Hydr Depth (m)	2.25	2.01
Min El Prs (m)	106.74	W.P. Total (m)	84.79	85.48
Delta EG (m)	0.3	Conv. Total (m3/s)		
Delta WS (m)	0.15	Top Width (m)	50.8	46.33
BR Open Area (m2)	39.41	Frctn Loss (m)		
BR Open Vel (m/s)	2.39	C & E Loss (m)		
Coef of Q		Shear Total (N/m2)		
Br Sel Method	Press/Weir	Power Total (N/m s)	-1599.12	-1549.33

Height of Vertical Exposed Face of Abutment	0.75	
Approx. Side Slope of channel below bridge	4	:1 (h:v)
Approx. channel bottpm width	6.40	
Hydraulic depth to mean bed elevation	2.52	
Hydraulic depth	1.91	

PRESSURE FLOW SCOUR

Live-Bed Vertical Contraction Scour ==========

$Y_s/Y_1 = -5.08 + 1.27 (Y_1 / H_b) + 4.44 (H_b / Y_1) + 0.19 (V_a / V_c) =$ **less than zero m** .....Eq. 6.21 (Arneson's Eq.)

Y_s =	**N/A m**	Depth of vertical contraction scour relative to mean bed elevation
Y_1 =	3.26 m	Depth of flow immediately upstream of the bridge (hydraulic depth at upstream face)
H_b =	1.91 m	Distance from the low chord of the bridge to the average elevation of the stream bed before scour
V_a =	2.39 m/s	Average velocity of the flow through the bridge opening before scour occurs
V_c =	2.01 m/s	Critical velocity of the D_{50} of the bed material in the bridge opening
D_{50} = (Design)	m	if different from the value used in the Contraction Scour computation

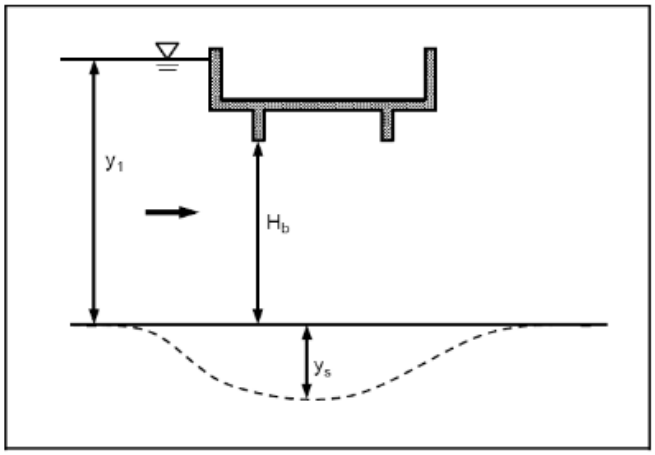
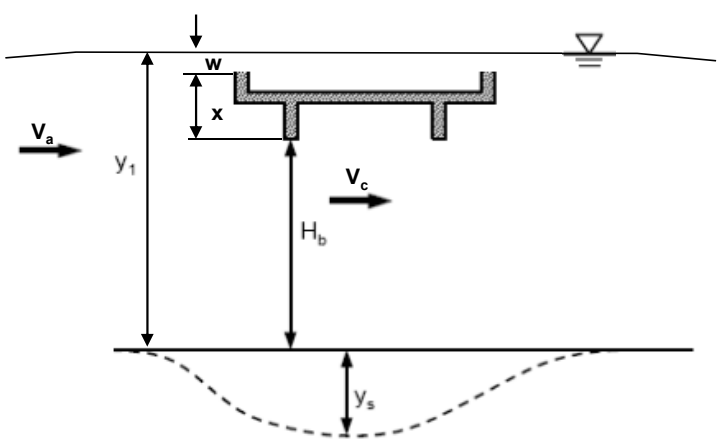


Figure 6.14. Definition sketch of vertical contraction scour resulting from pressure flow.

Clear-Water Contraction Scour ==========

$H_b + Y_s/Y_a = 1.1021 [(1 - w / Y_a) V_a / V_c]^{0.6031} =$ **0.68 m** .....HEC-18 (1995) App. B (Umbrell)

Y_s =	**0.00 m**	Depth of vertical scour **LIVE-BED controls. Ignore this procedure**
Y_a =	3.26 m	Depth of flow immediately upstream of the bridge (approch depth)
H_b =	1.91 m	Depth from the low chord of the bridge to original river bed
V_a =	1.49 m/s	Approach Velocity
V_c =	2.39 m/s	Velocity under the bridge deck. (V_c is equal to the incipient motion velocity)
w =	0.92 m	Depth of overflow



PROJECT NO. 151-273 **BRIDGE NO.** Pedestrian Crossing **UNIT:** Metric

Ref. HEC-18., May 2001 (4th ed.)

(October 2013 Note: These equation are still valid in HEC-18, 5th ed.)

SUMMARY

Contraction Scour			Type:	CLEAR-WATER	Depth:	0.00 m	Event:	500-YR
Local	East	Abut. #2	LEFT	Eq.: Froehlich	Depth:	1.05 m	Event:	500-YR
Abutment	West	Abut. #1	RIGHT	Eq.: Froehlich	Depth:	0.42 m	Event:	500-YR

CONTRACTION SCOUR

$V_c = K_u y^{1/6} D^{1/3}$ .....Eq. 5.1

= 1.98 *m/s* Critacal velocity above which bed material of size D and smaller will be transported

Ku = 6.19 m (6.19 in SI units; 11.17 in English units)

y = 1.84 m Average depth of flow upstream of the bridge

D = 0.024 m Particle size for Vc , *m* (use D_{50})

V = 1.88 *m/s* The mean velocity of the flow in the main channel or overbank area upstream of the brige opening

Vc > V ***Thus, CLEAR-WATER CONTRACTION SCOUR***

Live-Bed Contraction Scour ==========

$Y_2/Y_1 = (Q_2/Q_1)^{6/7} (W_1/W_2)^{k_1}$ = 0.93 .....Eq. 5.2

$Y_s = Y_2 - Y_o$ m .....Eq. 5.3

= N/A m Average contraction scour depth **CLEAR-WATER controls. Ignore this procedure**

Y_1 = 1.84 m Average depth in the upstream main channel

Y_2 = 1.72 m Average depth in the contracted section

Y_o = 1.91 m Existing depth in the contracted section before scour

Q_1 = 68.30 m3/s Flow in the upstream channel transporting sediment

Q_2 = 74.01 m3/s Flow in the contracted channel

W_1 = 16.34 m Bottom width of the upstream main channel that is transporting bed material

W_2 = 20.60 m Bottom width of the main channel in the contracted section less pier width

k_1 = 0.59 Exponent determined below (V^*/ω = 0.36)

V^* = 0.2241 $=(T_o/\rho)^{1/2}$ or $(gY1\ S1)^{1/2}$, shear velocity in the upstream section , m/s

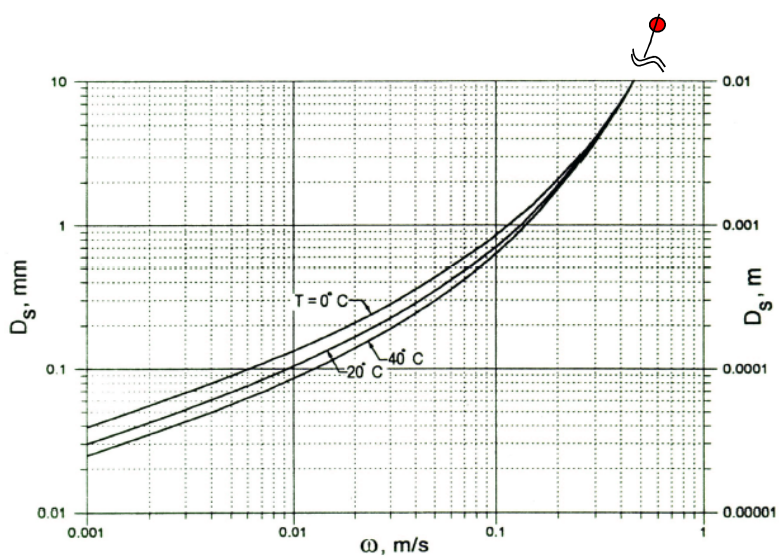
ω = 0.63 m/s Fall velocity of bed material based on the D_{50} (Figure 5.8)

g = 9.81 m/s^2 Acceleration of gravity

S1 = 0.001321 m/m Slope of energy gradeline of main channel

T_o = 50.22 Pa (N/m^2) Shear stess on the bed

ρ = 1000 kg/m^3 Density of water



V^*/ω	k1	*Mode of Bed Material Transport*
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

Figure 5.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Clear-Water Contraction Scour ==========

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2}\right]^{3/7}$$ .....Eq. 5.4

$$y_s = y_2 - y_o$$ **m** .....Eq. 5.5

=	**-0.24**	**m**	Average contraction scour depth
y_2 =	1.68	m	Average equilibrium depth in the contracted section after contraction scour
y_o =	1.91	m	Average existing depth in the contracted section
Q =	74.01	m3/s	Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W
W =	20.60	m	Bottom width of the contracted section less pier widths
K_u =	0.0250		(0.025 in SI units; 0.0077 in English units)
D_m =	0.0300	m	Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in th contacted setion
D_{50} =	0.0240	m	Median diameter of bed material

Because D_{50} is not the largest particle in the bed material, the scoured section can be slightly armored. Therefore, the D_m is assumed to be 1.25 D_{50}. For stratified bed material the depth of scour can be determined by using the clear-water scour equation sequentially with successive D_m of the bed material layers.

Data Source

Eq. 5.1			From:	RS
y =	1.84	m	D	1309
V =	1.88	m	D	1288.5 BR U

Eq. 5.2 & 5.3				
Y1 =	1.84	m	D	1309
Yo =	1.91	m	D	1288.5 BR U
Q1 =	68.301608	m3/s	D	1309
Q2 =	74.01	m3/s	D	1288.5 BR U
W1 =	16.34	m	D	1309
or	(n/a)	m (manual)		
W2 =	20.6	m	D	1288.5 BR U
or	(n/a)	m (manual)		
S1 =	0.001321	m/m	C	1309
To =	50.22	Pa (N/m^2)	C	1309
P2 =	0	m (pier width)		

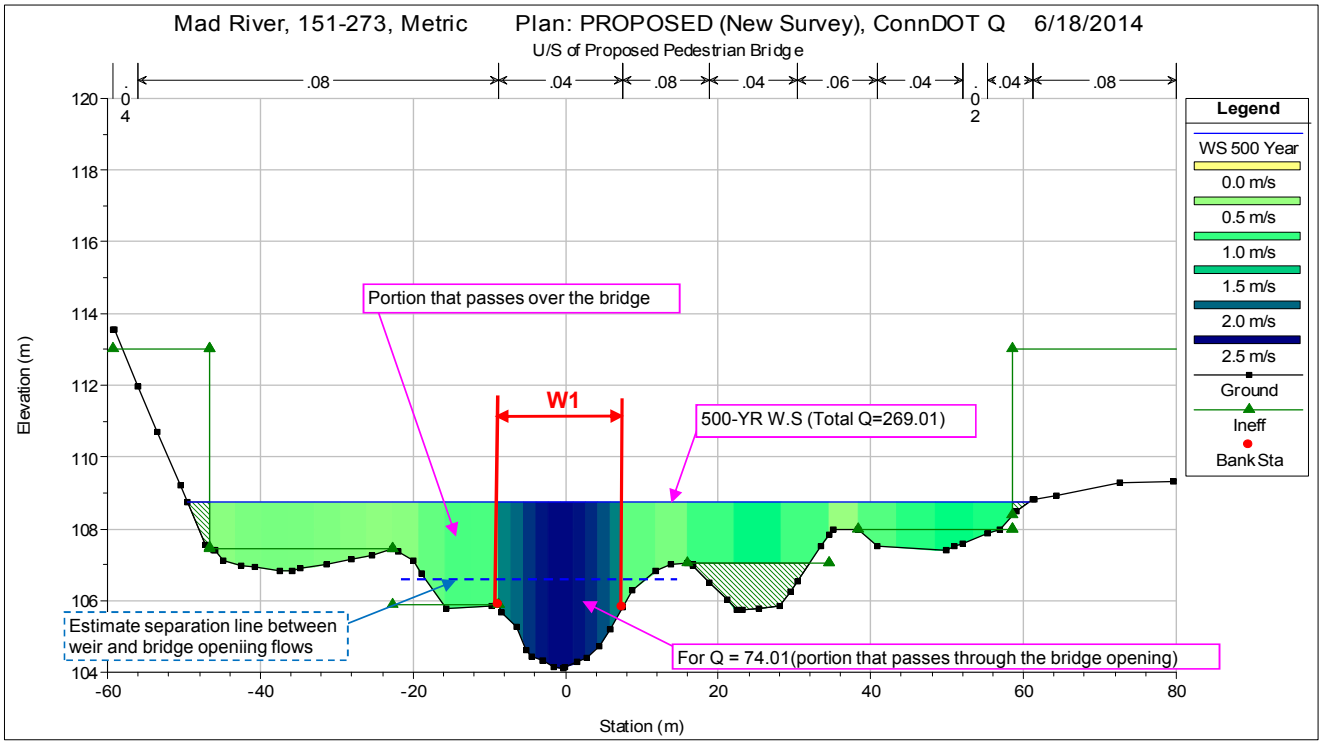
Eq. 5.4 & 5.5				
Q =	74.01	m3/s	C	1288.5
W =	20.6	m	C	1288.5
yo =	1.91	m	C	1288.5

Legends:

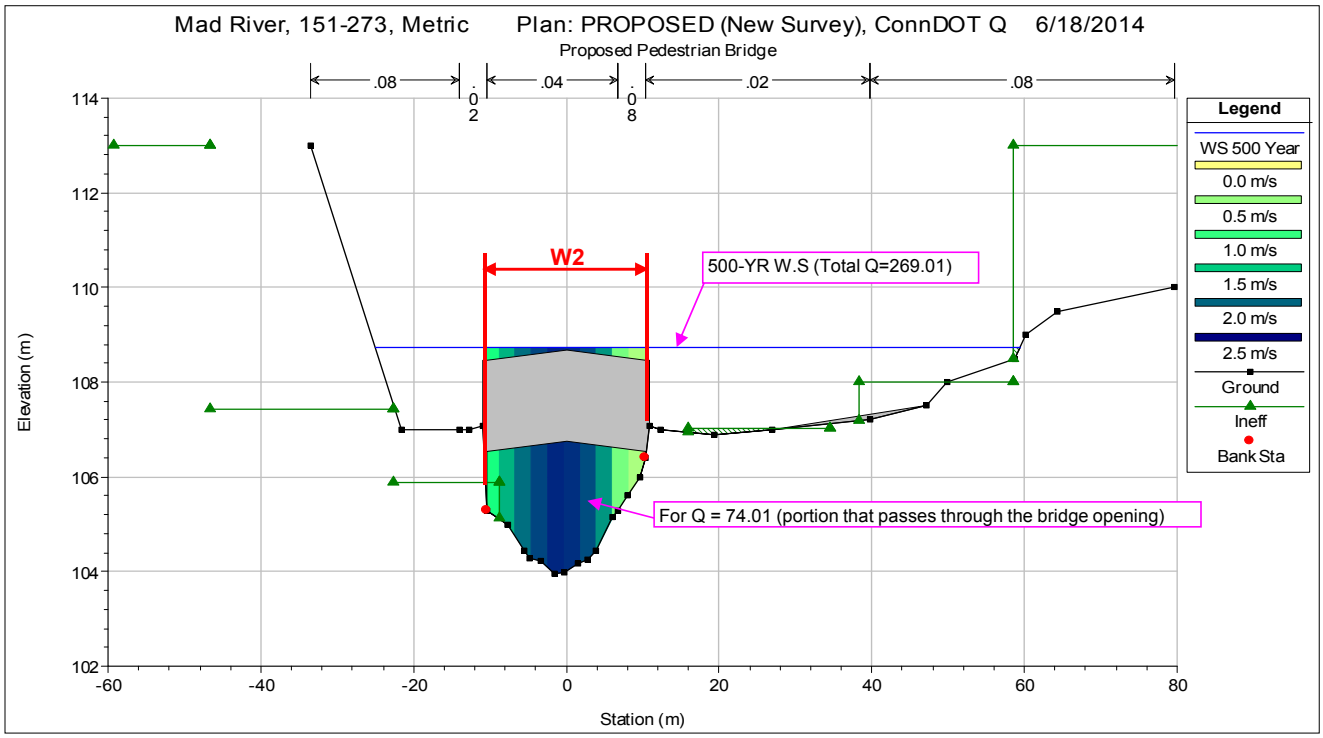
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections used for Contraction Scour Computations

UPSTREAM SECTION 1309



CONTRACTED SECTION 1288.5 BR U



*This drawing is intended to provide a basic, rough visualization of the scour depth. See Figure 5 for a more accurate depiction.

UPSTREAM CHANNEL SECTION

River Station 1309 Event: 500-YR

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computa*** No except channel stations

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 500 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	108.95	Element				
Vel Head (m)	0.16	Wt. n-Val.	0.08	0.04	0.049	
W.S. Elev (m)	108.73	Reach Len. (m)	19	19	19	
Crit W.S. (m)	107.78	Flow Area (m2)	73.79	65.33	72.94	
E.G. Slope (m/m)	0.001321	Area (m2)	75.85	65.33	86.38	227.56
Q Total (m3/s)	269.01	Flow (m3/s)	52.15	146.48	70.38	
Top Width (m)	110.21	Top Width (m)	40.67	16.34	53.2	
Vel Total (m/s)	1.27	Avg. Vel. (m/s)	0.71	2.24	0.96	
Max Chl Dpth (m)	4.61	Hydr. Depth (m)	1.95	4	1.43	2.06
Conv. Total (m3/s	7401.6	Conv. (m3/s)	1434.7	4030.3	1936.5	
Length Wtd. (m)	19	Wetted Per. (m)	38.04	16.85	51.82	
Min Ch El (m)	104.12	Shear (N/m2)	25.13	50.22	18.23	
Alpha	1.91	Stream Power (N/m s)	5742.47	0	0	
Frctn Loss (m)		Cum Volume (1000 m3	23.01	36.43	5.92	
C & E Loss (m)		Cum SA (1000 m2)	38.6	12.17	9.06	

	Flow dis. (data)	*manual*	Overflow? YES
Left WS Sta.		-49.51	-18.34
Left Flood Sta.			-18.34
Left Main Channel	-8.84		
Right Main Channel	7.5		
Right Flood Sta.			10.46
Right WS Sta.		60.7	10.46

Flow through the bridge opening only

L' (left)	9.5	L (left)	9.5
L' (Right)	2.96	L (Right)	2.96

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT		52.14	75.86			5.16	6.01
Main	16.34	146.48	65.31	1.84	2.24	68.30	30.02
Right		70.38	73.28			0.55	0.73

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 500 Year

Overflow Separation. Elev. (est.) 106.57 Ave. Dept 2.16

Pos		Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation Elev. (est.)	Overflow Separation Ave. Dept
1	LOB	-49.79	-46.6	0	2.06	3.2	0	0.71	0	8.33	0	0.00	0.00
2	LOB	-46.6	-43.17	3.01	5.23	3.47	1.12	1.53	0.58	19.55	11.26	0.00	0.00
3	LOB	-43.17	-39.75	3.93	6.11	3.43	1.46	1.78	0.64	23.09	14.85	0.00	0.00
4	LOB	-39.75	-36.32	4.31	6.46	3.43	1.6	1.88	0.67	24.41	16.29	0.00	0.00
5	LOB	-36.32	-32.9	4.19	6.35	3.43	1.56	1.85	0.66	23.99	15.83	0.00	0.00
6	LOB	-32.9	-29.47	3.67	5.87	3.43	1.37	1.71	0.63	22.17	13.88	0.00	0.00
7	LOB	-29.47	-26.05	3.16	5.36	3.43	1.17	1.56	0.59	20.24	11.92	0.00	0.00
8	LOB	-26.05	-22.62	2.64	4.82	3.43	0.98	1.41	0.55	18.19	9.98	0.00	0.00
9	LOB	-22.62	-19.18	3.01	5.26	3.51	1.12	1.53	0.57	19.38	11.1	0.00	0.00
10	LOB	-19.18	-15.73	6.37	8.32	3.59	2.37	2.42	0.77	29.99	22.97	0.63	0.87
11	LOB	-15.73	-12.29	9.04	10.09	3.45	3.36	2.93	0.9	37.89	33.92	2.35	2.66
12	LOB	-12.29	-8.84	8.81	9.93	3.45	3.27	2.88	0.89	37.35	33.12	2.18	2.48
13	Chan	-8.84	-7.21	9.58	5.13	1.71	3.56	3.14	1.87	38.87	72.53	3.00	1.61
14	Chan	-7.21	-5.57	11.52	5.77	1.74	4.28	3.53	2	42.97	85.75	4.44	2.23
15	Chan	-5.57	-3.94	15.31	6.8	1.71	5.69	4.16	2.25	51.44	115.73	7.39	3.28
16	Chan	-3.94	-2.3	17.22	7.18	1.64	6.4	4.4	2.4	56.6	135.71	8.72	3.64
17	Chan	-2.3	-0.67	18.45	7.48	1.64	6.86	4.58	2.47	59.04	145.61	9.75	3.96
18	Chan	-0.67	0.96	18.44	7.47	1.64	6.86	4.57	2.47	59.08	145.76	9.74	3.95
19	Chan	0.96	2.6	17.42	7.23	1.64	6.48	4.42	2.41	57.04	137.46	8.88	3.69
20	Chan	2.6	4.23	15.73	6.84	1.67	5.85	4.19	2.3	53.12	122.11	7.63	3.32
21	Chan	4.23	5.87	13	6.16	1.71	4.83	3.77	2.11	46.74	98.64	5.53	2.62
22	Chan	5.87	7.5	9.81	5.25	1.74	3.65	3.21	1.87	38.96	72.82	3.23	1.73
23	ROB	7.5	11.73	7.68	9.87	4.36	2.85	2.33	0.78	29.31	22.79	0.55	0.73
24	ROB	11.73	15.97	4.92	7.48	4.25	1.83	1.77	0.66	22.81	15.01	0.00	0.00
25	ROB	15.97	22.14	10.11	10.5	6.3	3.76	1.7	0.96	21.58	20.79	0.00	0.00
26	ROB	22.14	28.3	13.48	10.5	6.19	5.01	1.7	1.28	21.98	28.23	0.00	0.00
27	ROB	28.3	34.47	8.85	9.5	6.45	3.29	1.54	0.93	19.08	17.78	0.00	0.00
28	ROB	34.47	38.34	1.42	2.89	3.9	0.53	0.75	0.49	9.6	4.73	0.00	0.00
29	ROB	38.34	43.4	4.78	5.66	5.11	1.78	1.12	0.84	14.33	12.11	0.00	0.00
30	ROB	43.4	48.47	6.98	6.53	5.07	2.59	1.29	1.07	16.7	17.85	0.00	0.00
31	ROB	48.47	53.53	7.79	6.16	5.08	2.9	1.22	1.27	15.72	19.88	0.00	0.00
32	ROB	53.53	58.6	4.37	3.87	5.12	1.63	0.76	1.13	9.78	11.05	0.00	0.00
33	ROB	58.6	64	0	0.32	2.13	0	0.15	0	1.94	0	0.00	0.00
34												**74.02**	
35												Q Bridge	
36												74.01	
37													
38													
39													
40													
41													
42													
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49													
50													

CONTRACTED CHANNEL SECTION

River Station 1288.5 BR U

CROSS SECTION OUTPUT

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 500 Year

E.G. Elev (m)	108.89	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.34	Wt. n-Val.				
W.S. Elev (m)	108.73	Reach Len. (m)	3.5	3.5	3.5	
Crit W.S. (m)	107.55	Flow Area (m2)	23.84	45.98	72.09	
E.G. Slope (m/m)		Area (m2)	21.52	42.75	65.68	129.95
Q Total (m3/s)	269.01	Flow (m3/s)	41.64	79.42	124.54	
Top Width (m)	84.37	Top Width (m)	14.68	20.6	49.09	
Vel Total (m/s)	1.9	Avg. Vel. (m/s)	1.75	1.73	1.73	
Max Chl Dpth (m)	4.77	Hydr. Depth (m)	1.62	2.23	1.49	1.54
Conv. Total (m3/s		Conv. (m3/s)				
Length Wtd. (m)	3.5	Wetted Per. (m)	16.46	63.68	49.74	
Min Ch El (m)	103.96	Shear (N/m2)				
Alpha	1.55	Stream Power (N/m s)	3816.83	0	0	
Frctn Loss (m)		Cum Volume (1000 m3	22.09	35.4	4.47	
C & E Loss (m)		Cum SA (1000 m2)	38.08	11.82	8.08	

		Flow dis.	*manual*	Overflow?	YES
Left WS Sta.			-10.3	8.17	Flow through the bridge opening only
Left Flood Sta.				8.17	
Left Main Channel		-10.3			
Right Main Channel		10.3			
Right Flood Sta.				10.3	
Right WS Sta.			10.3	10.3	
L' (left)	-10.3	L (left)	0		
L' (Right)	-10.3	L (Right)	0		

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT							
Main	20.6	74.01	39.41	1.91	1.88	74.01	39.41
Right							

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 108.73	Ave. Dept 0
1	Chan	-10.3	-8.84	2.24	1.96	4.18	3.02	1.34	1.14	0	0	2.24	1.96
2	Chan	-8.84	-6.71	5.51	3.4	4.29	7.44	1.6	1.62	0	0	5.51	3.40
3	Chan	-6.71	-4.59	8.87	4.54	4.31	11.98	2.13	1.96	0	0	8.87	4.54
4	Chan	-4.59	-2.46	11.28	5.22	4.27	15.24	2.45	2.16	0	0	11.28	5.22
5	Chan	-2.46	-0.33	13.38	5.78	4.26	18.08	2.72	2.32	0	0	13.38	5.78
6	Chan	-0.33	1.79	12.73	5.61	4.26	17.2	2.64	2.27	0	0	12.73	5.61
7	Chan	1.79	3.92	10.78	5.08	4.27	14.57	2.39	2.12	0	0	10.78	5.08
8	Chan	3.92	6.05	6.94	3.93	4.36	9.38	1.85	1.77	0	0	6.94	3.93
9	Chan	6.05	8.17	1.74	2.58	4.31	2.35	1.22	0.67	0	0	1.74	2.58
10	Chan	8.17	10.3	0.54	1.31	4.55	0.73	0.62	0.41	0	0	0.54	1.31
11												**74.01**	
12												Q Bridge	
13												74.01	

LIVE SCOUR AT ABUTMENTS

Froehlich's Live-Bed Abutment Scour Equation — *LEFT* — *RIGHT* — ==========

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 1 =$ — **2.66** — **1.23** — .....Eq. 7.1

Amended Local Scour Equation

$Ys/Ya = 2.27\ K_1\ K_2\ (L'/Ya)^{0.43}\ Fr^{0.61} + 0.05 =$ — **1.71** — **0.28** — .....CT DOT DM Pg 9B-2

	LEFT	*RIGHT*		
Ys =	**1.05**	**0.42**	**m**	Scour depth <== using Amended equation
K_1 =	1.00	0.82		Coeffcient for abutment shape (see Table 7.1 and Figrue 7.6)
K_2 =	0.91	1.06		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
θ =	43	138		
				θ < 90 degrees if embankment points downstream
				θ > 90 degrees if embankment points upstream
				(see Figure 7.5 for definition of θ)
L' =	1.66	0.10	m	Length of active flow obstructed by the embankment (see Figure 7.4)
Ae =	4.96	0.25	m^2	Flow area of the approach cross section obstructed by the embankment
Fr =	0.35	0.20		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment
Ve =	0.86	0.75	m/s	Qe/Ae
Qe =	4.247678	0.188121	m^3/s	Flow obstructed by the abutment and approach embankment
Ya =	0.62	1.48	m	Ae/L, Average depth of flow on the floodplain
L =	8.051	0.1682	m	Length of embankment projected normal to the flow

Table 7.1. Abutment Shape Coefficients.

Description	K_1
Vertical-wall abutment	1.00
Vertical-wall abutment with wing walls	0.82
Spill-through abutment	0.55

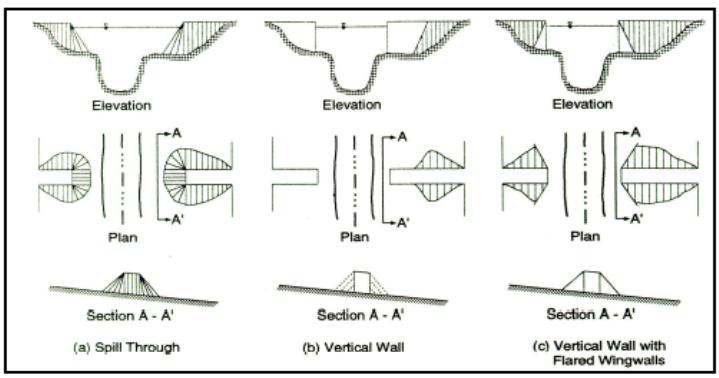


Figure 7.6. Abutment shape.

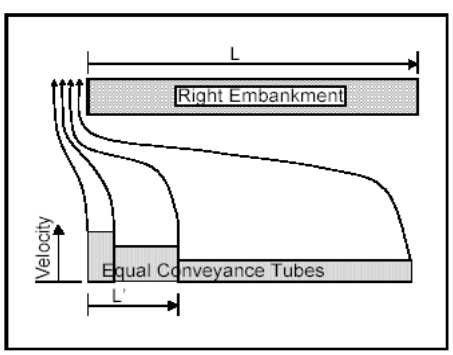


Figure 7.4. Determination of length of embankment blocking live flow for abutment scour estimation.

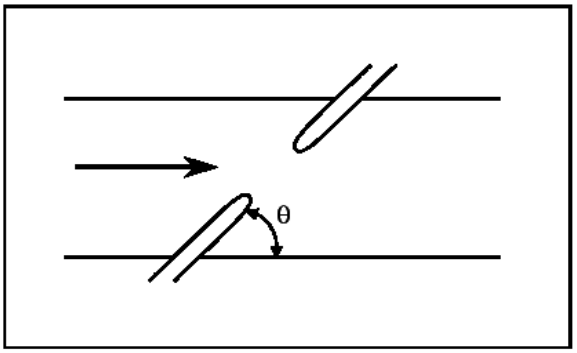


Figure 7.5. Orientation of embankment angle, θ, to the flow.

HIRE Live-Bed Abutment Scour Equation ==========

		LEFT	RIGHT	
Applicability check:	L/Y_1 =	4	0	*Use HIRE Eq. only if L/Y_1 > 25*
Y_s/Y_1 = 4 $Fr^{0.33}$ K_1/0.55 K_2 =		**N/A**	**N/A**	.....Eq. 7.1

	LEFT	RIGHT		
Y_s =	**N/A**	**N/A**	**m**	Scour depth (N/A if L/Y_1 < 25)
K1 =	1.00	0.82		Coeffcient for abutment shape (see Table 7.1 on RIGHT)
K2 =	0.91	1.06		$(\theta/90)^{0.13}$, Coefficient for angle of embankment to flow
Y1 =	1.84	1.84	m	Depth of flow at the abutment on the overbank or in the main channel,
Fr =	0.35	0.20		Ve/(gYa)^0.5, Froude Number of approach flow upstream of the abutment

Data Source

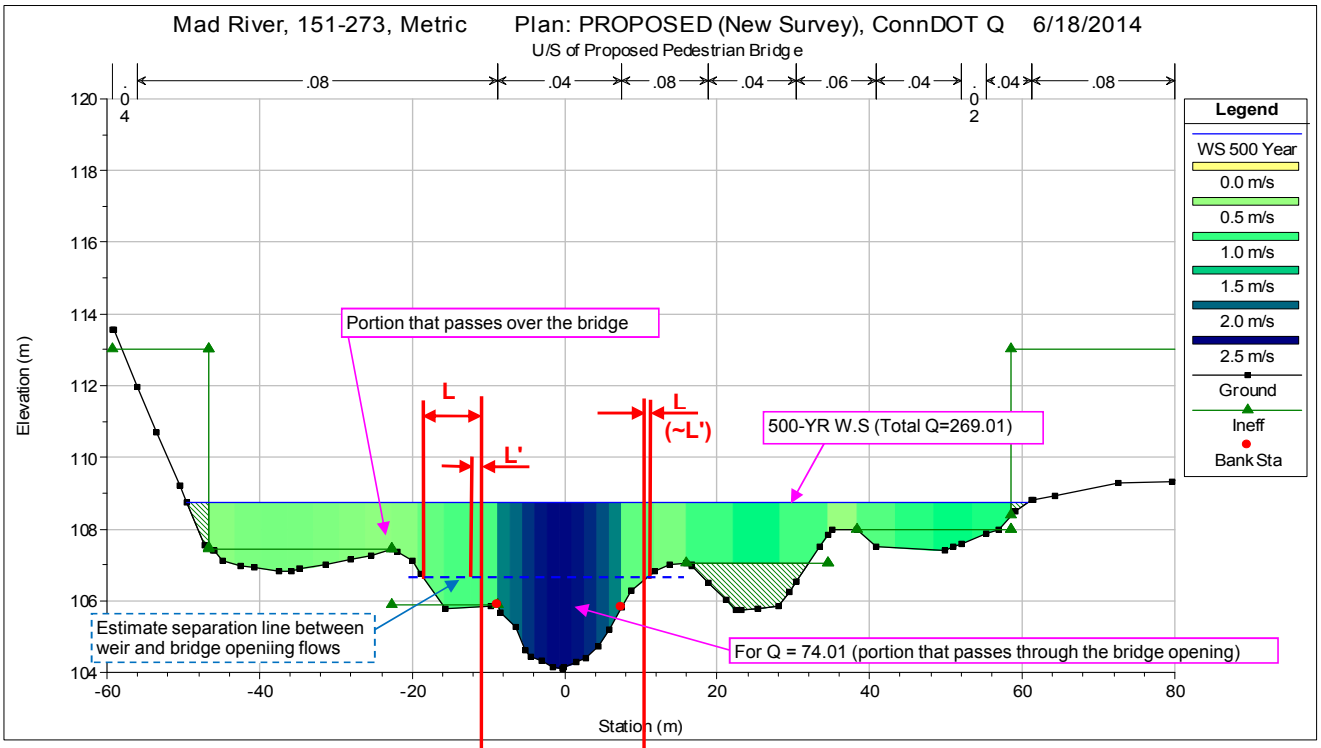
Eq. 7.1			From:	RS
LT			UC	
	L' =	1.6572 m	D	1309
	Ae =	4.9648 m2	D	1309
	Qe =	4.2477 m3/s	D	1309
	L =	8.051 m	D	1309
RT			UC	
	L' =	0.1035 m	D	1309
	Ae =	0.2493 m2	D	1309
	Qe =	0.1881 m3/s	D	1309
	L =	0.1682 m	D	1309

Legends:

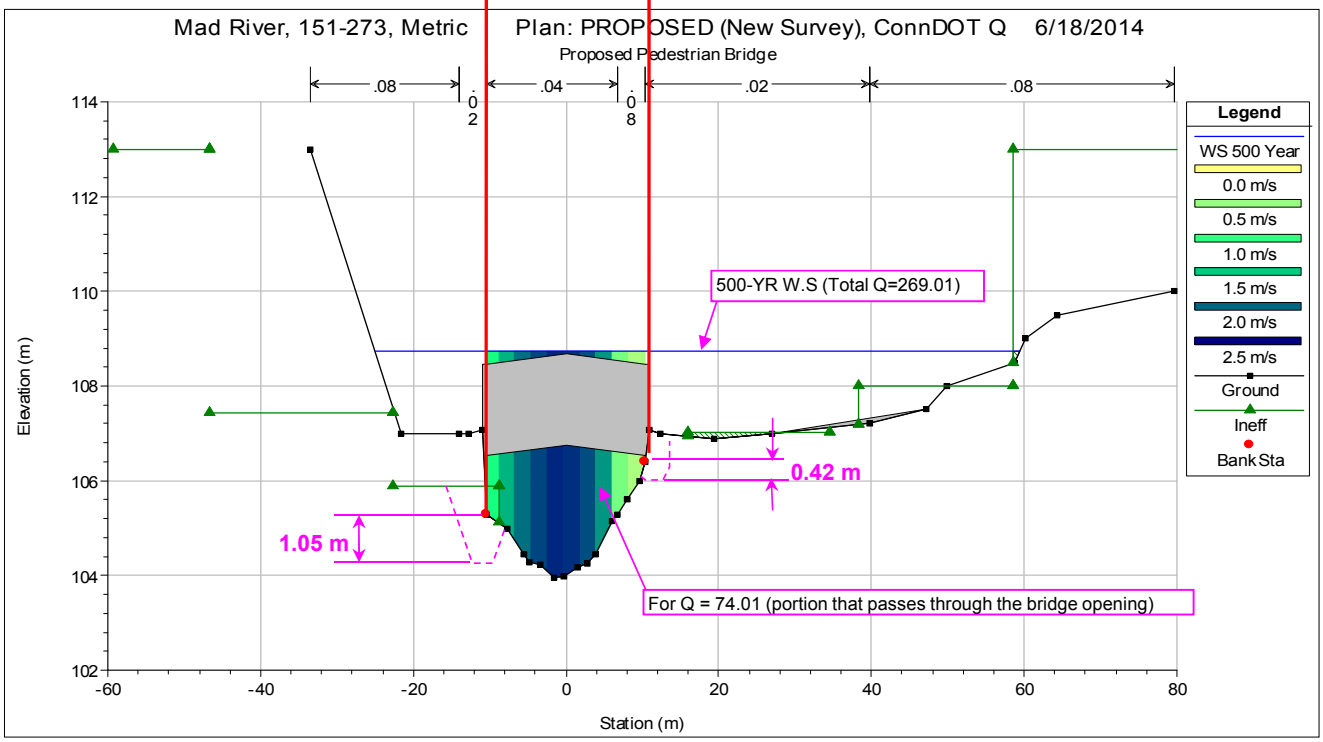
UC	from an upstream Cross Section output (approach section)
UF	from Bridge Upstream Face - Cross Section output (BR U); or Bridge Downstream Face (BR D) - this is seldom used
T	based on the flow data for the entire section
C	data from "Channel" column in the HEC-RAS Cross Section Output
D	from evaluting Flow Distribtion Output and resetting "Channel" and "Overbank" limits
M	manual data entry

Cross Sections Used for Local Abutment Scour Computations

APPROACH SECTION 1309



1288.5 BR U **1288.5 BR U**



** This drawing is intended to provide a basic, rough visualization of the scour depth. See Figure 5 for a more accurate depiction of combined total scour*

UPSTREAM APPROACH CHANNEL SECTIO *River Station* 1309 Event: 500-YR

CROSS SECTION OUTPUT *Use the same data as in the contraction scour computatio* YES except channel stations

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 500 Year

E.G. Elev (m)	108.95	Element	Left OB	Channel	Right OB	Total
Vel Head (m)	0.16	Wt. n-Val.	0.08	0.04	0.049	
W.S. Elev (m)	108.73	Reach Len. (m)	19	19	19	
Crit W.S. (m)	107.78	Flow Area (m2)	73.79	65.33	72.94	
E.G. Slope (m/m)	0.001321	Area (m2)	75.85	65.33	86.38	227.56
Q Total (m3/s)	269.01	Flow (m3/s)	52.15	146.48	70.38	
Top Width (m)	110.21	Top Width (m)	40.67	16.34	53.2	
Vel Total (m/s)	1.27	Avg. Vel. (m/s)	0.71	2.24	0.96	
Max Chl Dpth (m)	4.61	Hydr. Depth (m)	1.95	4	1.43	2.06
Conv. Total (m3/s)	7401.6	Conv. (m3/s)	1434.7	4030.3	1936.5	
Length Wtd. (m)	19	Wetted Per. (m)	38.04	16.85	51.82	
Min Ch El (m)	104.12	Shear (N/m2)	25.13	50.22	18.23	
Alpha	1.91	Stream Power (N/m s)	5742.47	0	0	
Frctn Loss (m)		Cum Volume (1000 m:	23.01	36.43	5.92	
C & E Loss (m)		Cum SA (1000 m2)	38.6	12.17	9.06	

	Flow dis. (data)	*manual*	Overflow?	YES
Left WS Sta.		-49.51	-18.34	Flow through the bridge opening only
Left Eff. WS Sta.	-19.18	-15.73	-11.95	
Left Abutmnt Sta.	-10.29			
Right Abutmnt Sta.	10.29			
Right Eff. WS Sta.	29.18	15.97	10.40	
Right WS Sta.		60.7	10.46	

L' (left)	1.657	L (left)	8.051
L' (Right)	0.104	L (Right)	0.168

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT		48.4398	71.6894			4.25	4.96
Main	20.5808	155.249	75.9948	1.53	2.04	69.58	31.54
Right		41.3912	41.3358			0.19	0.25

Plan: PR_DOT Mad River Reach 1 RS: 1309 Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 106.57	Ave. Dept 2.16
1	LOB	-49.79	-46.6	0	2.06	3.2	0	0.71	0	8.33	0	0.00	0.00
2	LOB	-46.6	-43.17	3.01	5.23	3.47	1.12	1.53	0.58	19.55	11.26	0.00	0.00
3	LOB	-43.17	-39.75	3.93	6.11	3.43	1.46	1.78	0.64	23.09	14.85	0.00	0.00
4	LOB	-39.75	-36.32	4.31	6.46	3.43	1.6	1.88	0.67	24.41	16.29	0.00	0.00
5	LOB	-36.32	-32.9	4.19	6.35	3.43	1.56	1.85	0.66	23.99	15.83	0.00	0.00
6	LOB	-32.9	-29.47	3.67	5.87	3.43	1.37	1.71	0.63	22.17	13.88	0.00	0.00
7	LOB	-29.47	-26.05	3.16	5.36	3.43	1.17	1.56	0.59	20.24	11.92	0.00	0.00
8	LOB	-26.05	-22.62	2.64	4.82	3.43	0.98	1.41	0.55	18.19	9.98	0.00	0.00
9	LOB	-22.62	-19.18	3.01	5.26	3.51	1.12	1.53	0.57	19.38	11.1	0.00	0.00
10	LOB	-19.18	-15.73	6.37	8.32	3.59	2.37	2.42	0.77	29.99	22.97	0.63	0.87
11	LOB	-15.73	-12.29	9.04	10.09	3.45	3.36	2.93	0.9	37.89	33.92	2.35	2.66
12	LOB	-12.29	-8.84	8.81	9.93	3.45	3.27	2.88	0.89	37.35	33.12	2.18	2.48
13	Chan	-8.84	-7.21	9.58	5.13	1.71	3.56	3.14	1.87	38.87	72.53	3.00	1.61
14	Chan	-7.21	-5.57	11.52	5.77	1.74	4.28	3.53	2	42.97	85.75	4.44	2.23
15	Chan	-5.57	-3.94	15.31	6.8	1.71	5.69	4.16	2.25	51.44	115.73	7.39	3.28
16	Chan	-3.94	-2.3	17.22	7.18	1.64	6.4	4.4	2.4	56.6	135.71	8.72	3.64
17	Chan	-2.3	-0.67	18.45	7.48	1.64	6.86	4.58	2.47	59.04	145.61	9.75	3.96
18	Chan	-0.67	0.96	18.44	7.47	1.64	6.86	4.57	2.47	59.08	145.76	9.74	3.95
19	Chan	0.96	2.6	17.42	7.23	1.64	6.48	4.42	2.41	57.04	137.46	8.88	3.69
20	Chan	2.6	4.23	15.73	6.84	1.67	5.85	4.19	2.3	53.12	122.11	7.63	3.32
21	Chan	4.23	5.87	13	6.16	1.71	4.83	3.77	2.11	46.74	98.64	5.53	2.62
22	Chan	5.87	7.5	9.81	5.25	1.74	3.65	3.21	1.87	38.96	72.82	3.23	1.73
23	ROB	7.5	11.73	7.68	9.87	4.36	2.85	2.33	0.78	29.31	22.79	0.55	0.73
24	ROB	11.73	15.97	4.92	7.48	4.25	1.83	1.77	0.66	22.81	15.01	0.00	0.00
25	ROB	15.97	22.14	10.11	10.5	6.3	3.76	1.7	0.96	21.58	20.79	0.00	0.00
26	ROB	22.14	28.3	13.48	10.5	6.19	5.01	1.7	1.28	21.98	28.23	0.00	0.00
27	ROB	28.3	34.47	8.85	9.5	6.45	3.29	1.54	0.93	19.08	17.78	0.00	0.00
28	ROB	34.47	38.34	1.42	2.89	3.9	0.53	0.75	0.49	9.6	4.73	0.00	0.00
29	ROB	38.34	43.4	4.78	5.66	5.11	1.78	1.12	0.84	14.33	12.11	0.00	0.00
30	ROB	43.4	48.47	6.98	6.53	5.07	2.59	1.29	1.07	16.7	17.85	0.00	0.00
31	ROB	48.47	53.53	7.79	6.16	5.08	2.9	1.22	1.27	15.72	19.88	0.00	0.00
32	ROB	53.53	58.6	4.37	3.87	5.12	1.63	0.76	1.13	9.78	11.05	0.00	0.00
33	ROB	58.6	64	0	0.32	2.13	0	0.15	0	1.94	0	0.00	0.00
34												**74.02**	
35												Q Bridge	
36												74.01	

	Left	Right
Computed L' = Q_e/q_{tube} =	***1.657***	***0.104***
Q_e:	4.25	0.19
V_{tube}:	0.89	0.78
y_{tube}:	2.88	2.33
q_{tube}:	2.563	1.817

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BRIDGE SECTION

River Station 1288.5 BR U

CROSS SECTION OUTPUT ***Use the same data as in the contraction scour computatic*** Yes

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 500 Year

			Left OB	Channel	Right OB	Total
E.G. Elev (m)	108.89	Element				
Vel Head (m)	0.34	Wt. n-Val.				
W.S. Elev (m)	108.73	Reach Len. (m)	3.5	3.5	3.5	
Crit W.S. (m)	107.55	Flow Area (m2)	23.84	45.98	72.09	
E.G. Slope (m/m)		Area (m2)	21.52	42.75	65.68	129.95
Q Total (m3/s)	269.01	Flow (m3/s)	41.64	79.42	124.54	
Top Width (m)	84.37	Top Width (m)	14.68	20.6	49.09	
Vel Total (m/s)	1.9	Avg. Vel. (m/s)	1.75	1.73	1.73	
Max Chl Dpth (m)	4.77	Hydr. Depth (m)	1.62	2.23	1.49	1.54
Conv. Total (m3/s)		Conv. (m3/s)				
Length Wtd. (m)	3.5	Wetted Per. (m)	16.46	63.68	49.74	
Min Ch El (m)	103.96	Shear (N/m2)				
Alpha	1.55	Stream Power (N/m s)	3816.83	0	0	
Frctn Loss (m)		Cum Volume (1000 m:	22.09	35.4	4.47	
C & E Loss (m)		Cum SA (1000 m2)	38.08	11.82	8.08	

					Flow dis.	*manual*
Left WS Sta.						-10.3
Left Eff. WS Sta.						0
Left Abutmnt Sta.					-10.3	
Right Abutmnt Sta.					10.3	
Right Eff. WS Sta.						0
Right WS Sta.						10.3
L' (left)	-10.3	L (left)	0			
L' (Right)	-10.3	L (Right)	0			

Overflow? YES

Flow through the bridge opening only

FLOW DISTRIBUTION IN CROSS SECTION OUTPUT

	W1	Q1, Qe	Area	Y1	V1	Reduced Q1, Qe	Reduced Area
LEFT							
Main	20.6	74.01	39.41	1.91	1.88	74.01	39.41
Right							

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 BR U Profile: 500 Year

	Pos	Left Sta (m)	Right Sta (m)	Flow (m3/s)	Area (m2)	W.P. (m)	Percent Conv	Hydr Depth(m)	Velocity (m/s)	Shear (N/m2)	Power (N/m s)	Overflow Separation. Elev. (est.) 108.73	Ave. Dept 0
1	Chan	-10.3	-8.84	2.24	1.96	4.18	3.02	1.34	1.14	0	0	2.24	1.96
2	Chan	-8.84	-6.71	5.51	3.4	4.29	7.44	1.6	1.62	0	0	5.51	3.40
3	Chan	-6.71	-4.59	8.87	4.54	4.31	11.98	2.13	1.96	0	0	8.87	4.54
4	Chan	-4.59	-2.46	11.28	5.22	4.27	15.24	2.45	2.16	0	0	11.28	5.22
5	Chan	-2.46	-0.33	13.38	5.78	4.26	18.08	2.72	2.32	0	0	13.38	5.78
6	Chan	-0.33	1.79	12.73	5.61	4.26	17.2	2.64	2.27	0	0	12.73	5.61
7	Chan	1.79	3.92	10.78	5.08	4.27	14.57	2.39	2.12	0	0	10.78	5.08
8	Chan	3.92	6.05	6.94	3.93	4.36	9.38	1.85	1.77	0	0	6.94	3.93
9	Chan	6.05	8.17	1.74	2.58	4.31	2.35	1.22	0.67	0	0	1.74	2.58
10	Chan	8.17	10.3	0.54	1.31	4.55	0.73	0.62	0.41	0	0	0.54	1.31
11												**74.01**	
12												Q Bridge	
13												74.01	
14													
15													
16													
17													
18													
19													
20													

BRIDGE OUTPUT

River Station 1288.5

Low Chord Elev.	106.54
Mean Channelbed Elev.	104.63
Bridge Opening Width	20.6

Plan: PR_DOT Mad River Reach 1 RS: 1288.5 Profile: 500 Year

			Inside BR U	Inside BR DS
E.G. US. (m)	108.95	Element		
W.S. US. (m)	108.73	E.G. Elev (m)	108.89	108.89
Q Total (m3/s)	269.01	W.S. Elev (m)	108.73	108.67
Q Bridge (m3/s)	74.01	Crit W.S. (m)	107.55	107.66
Q Weir (m3/s)	180.17	Max Chl Dpth (m)	4.77	4.71
Weir Sta Lft (m)	-25.29	Vel Total (m/s)	1.9	2.25
Weir Sta Rgt (m)	58.6	Flow Area (m2)	141.92	119.55
Weir Submerg	0.86	Froude # Chl	0.38	0.45
Weir Max Depth (m	1.95	Specif Force (m3)	258.21	253.63
Min El Weir Flow (n	106.97	Hydr Depth (m)	1.7	1.91
Min El Prs (m)	106.74	W.P. Total (m)	129.88	109.49
Delta EG (m)	0.13	Conv. Total (m3/s)		
Delta WS (m)	0.06	Top Width (m)	84.37	74.5
BR Open Area (m2	39.41	Frctn Loss (m)		
BR Open Vel (m/s)	1.88	C & E Loss (m)		
Coef of Q		Shear Total (N/m2)		
Br Sel Method	Press/Weir	Power Total (N/m s)	-1599.12	-1549.33

Height of Vertical Exposed Face of Abutment	0.75	
Approx. Side Slope of channel below bridge	4	:1 (h:v)
Approx. channel bottpm width	6.40	
Hydraulic depth to mean bed elevation	2.52	
Hydraulic depth	1.91	

PRESSURE FLOW SCOUR

Live-Bed Vertical Contraction Scour ==========

$Y_s/Y_1 = -5.08 + 1.27 (Y_1 / H_b) + 4.44 (H_b / Y_1) + 0.19 (V_a / V_c) =$ **less than zero m** .....Eq. 6.21

CLEAR-WATER controls. Ignore this procedure (Arneson's Eq.)

Y_s =	**N/A m**	Depth of vertical contraction scour relative to mean bed elevation	
Y_1 =	4.10 m	Depth of flow immediately upstream of the bridge (hydraulic depth at upstream face)	
H_b =	1.91 m	Distance from the low chord of the bridge to the average elevation of the stream bed before scour	
V_a =	1.88 m/s	Average velocity of the flow through the bridge opening before scour occurs	
V_c =	1.98 m/s	Critical velocity of the D_{50} of the bed material in the bridge opening	
	D_{50} = (Design)	m	if different from the value used in the Contraction Scour computation

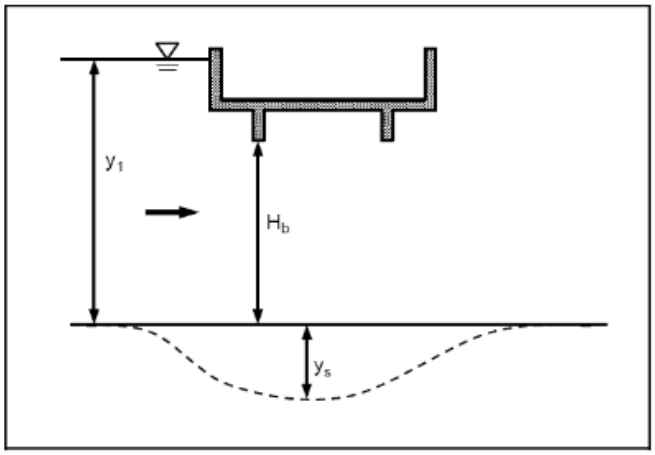
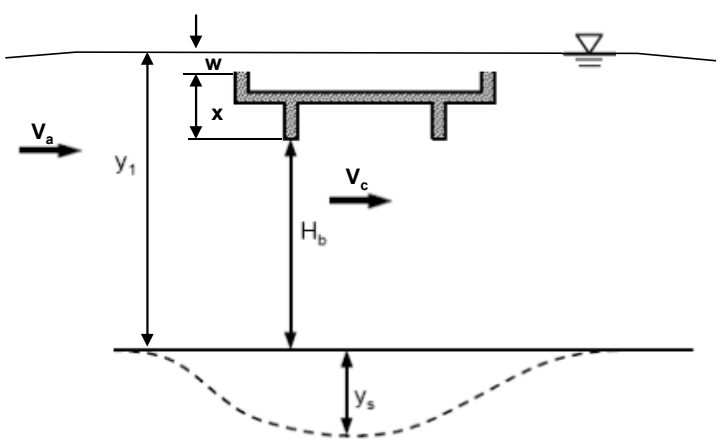


Figure 6.14. Definition sketch of vertical contraction scour resulting from pressure flow.

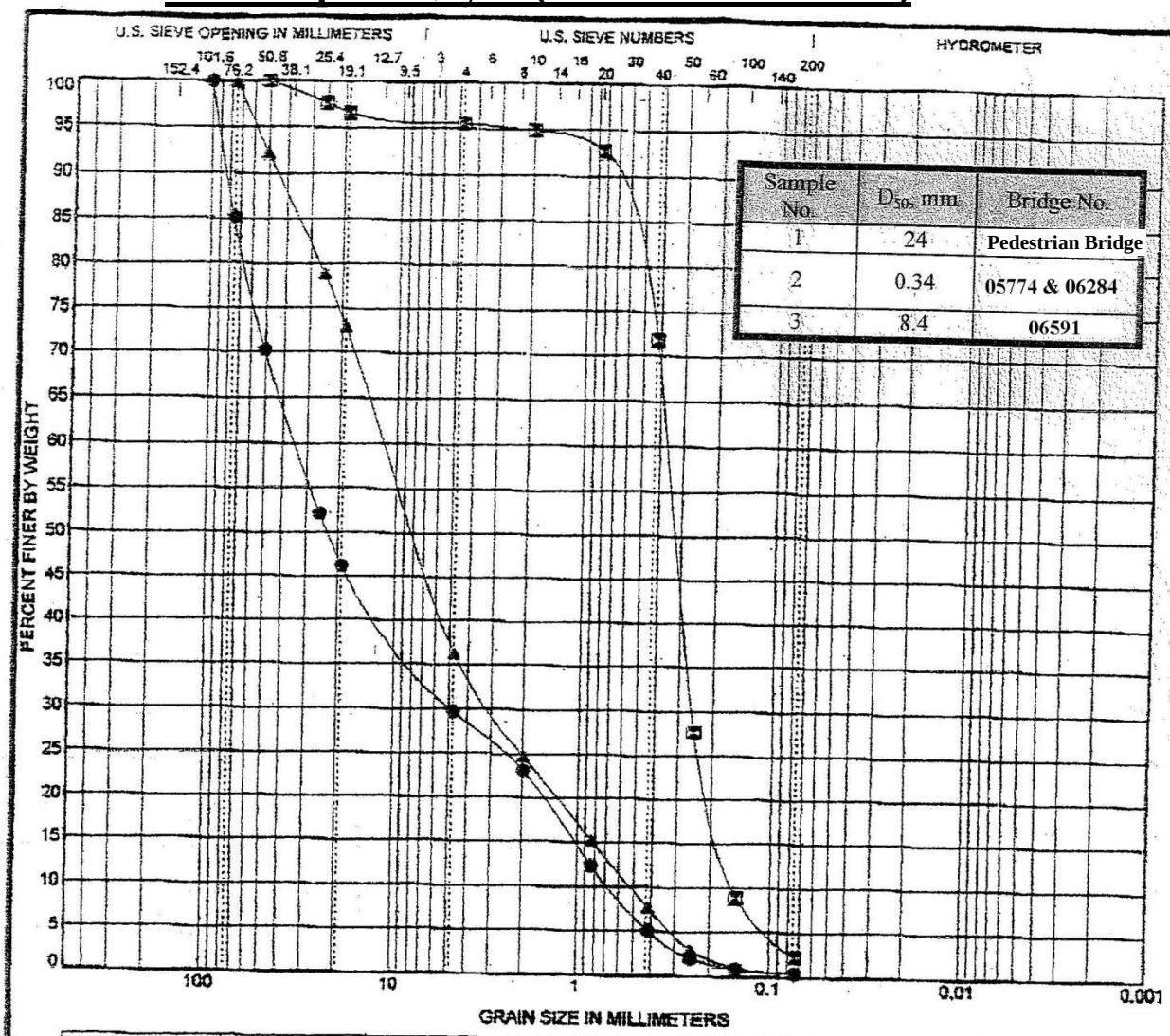
Clear-Water Contraction Scour ==========

$H_b + Y_s/Y_a = 1.1021 [(1 - w / Y_a) V_a / V_c]^{0.6031} =$ **0.60 m** .....HEC-18 (1995) App. B (Umbrell)

Y_s =	**N/A m**	Depth of vertical scour	**<- computed depth is less than zero**
Y_a =	4.10 m	Depth of flow immediately upstream of the bridge (approch depth)	
H_b =	1.91 m	Depth from the low chord of the bridge to original river bed	
V_a =	1.27 m/s	Approach Velocity	
V_c =	1.98 m/s	Velocity under the bridge deck. (V_c is equal to the incipient motion velocity)	
w =	1.76 m	Depth of overflow	



Soil Sample Analysis (Streambed Material)



Sample No.	D_{50}, mm	Bridge No.
1	24	Pedestrian Bridge
2	0.34	05774 & 06284
3	8.4	06591

	COBBLES	% GRAVEL			% SAND		% FINES	
		COARSE	MEDIUM	FINE	COARSE	FINE	% SILT	% CLAY
●	14.9	32.4	14.3	14.8	18.0	4.7	0.4	
■	0.0	2.4	1.5	1.1	23.2	68.6	2.2	
▲	0.0	20.8	24.5	29.8	17.0	7.2	0.5	

	Expl. No.	Sample No.	Depth (m)	LL	PL	PI	Water Content (%)	Cc	Cu
●	TP	1					6.2	1.04	51.02
■	TP	2					21.2	1.17	2.38
▲	TP	3					5.6	1.46	22.48

Sample Description

● Brown coarse to fine GRAVEL, little cobbles, little coarse sand, trace fine sand

■ Light brown coarse to fine SAND, trace coarse to fine gravel, trace silt

▲ Orange brown coarse to fine GRAVEL, little coarse sand, trace fine sand

Remarks:

HALEY & ALDRICH
Glastonbury, Connecticut

I-84 Reconstruction
Waterbury, Connecticut
State Project No.:

GRAIN SIZE DISTRIBUTION

Date: 12/17/2000

File No.: 91313-100

CONN DOT SIEVE 913136.GPJ HA LAB.GDT 12/20/00

Appendix C: Riprap Revetment Calculations

- HEC-11 Computation for 50-Year Only (Highest Flow Velocity)
- U.S. ACOE, EM 1110-2-1601
- Filter Layer Check
    - Standard Riprap to Granular Fill
    - Granular Fill to native material
    - Soil Sample Analysis (channel bank, using S4-3)

Connecticut Department of Transportation

Project No.	**Pedestrian Bridge**	**Prepared by**	WS	**Date**	4/14/2014
Route No.	**I-84**	**Checked by**		**Date**	
Town	**Waterbury**	**Stream**	Mad River		
Discharge	**50 Year**	**Unit**	Metric		

Riprap Revetment Design Based on HEC-11

$$D_{50} = 0.00594\ Va^3/(d_{avg} 0.5\ K_1^{1.5})\ C_{sf}$$

Average velocity (Va) and Average flow depth(d ave) in main channel

Cross Section No.	1288.5 BR	Va (m/s)=	2.50
Flow Area (sq.m)=	39.41	Top Width (m)=	20.80
d avg (m) =	1.89		
Side Slope=	2 : 1	Bank angle (degrees) θ =	26.6

Riprap Class	Φ	K_1	D_{50}	Acceptable Range	Check
Modified	41.2	0.7342	**0.11**	d50 < 0.13m	G
Intermediate	41.6	0.7391	**0.11**	0.13m<d50<0.20m	G
Standard	41.8	0.7415	**0.11**	0.20m<d50<0.38m	G
Other	42	0.7438	**0.11**	d50>0.38m	

Assumed Specific Gravity of Rock Riprap = 2.65
Angle of Repose (degrees)= Φ
Bank Stability Factor =K1
Median riprap particle size (m) for Stabilty Factor of 1.2 = D50
use larger Stability Factor if applying at channel bends

Stability Factors (SF) and Correction Factor (C_{sf})

SF	C_{sf}	D_{50} (Φ = 41.2)	D_{50} (Φ = 41.6)	D_{50} (Φ = 41.8)	D_{50} | Φ = 42
1.0	0.76	**0.08**	**0.08**	**0.08**	**0.08**
1.1	0.88	**0.09**	**0.09**	**0.09**	**0.09**
1.2	1.00	**0.11**	**0.11**	**0.11**	**0.11**
1.3	1.13	**0.12**	**0.12**	**0.12**	**0.12**
1.4	1.26	**0.14**	**0.13**	**0.13**	**0.13**
1.5	1.40	**0.15**	**0.15**	**0.15**	**0.15**
1.6	1.54	**0.17**	**0.16**	**0.16**	**0.16**
1.7	1.69	**0.18**	**0.18**	**0.18**	**0.18**
1.8	1.84	**0.20**	**0.19**	**0.19**	**0.19**
1.9	1.99	**0.21**	**0.21**	**0.21**	**0.21**
2.0	2.15	**0.23**	**0.23**	**0.23**	**0.23**

Recommendation: Standard Riprap is adequate

Flow Variables For Other Frequency discharges

		Vel Chnl	Flow Area	Top Width
		(m/s)	(m2)	(m)
1288.5 BR	19-YR(OVT)	2.18	39.41	20.8
	10 Year	2.02	32.99	20.49
	25 Year	2.28	39.41	20.8
	50 Year	**2.50**	**39.41**	**20.8**
	100 Year	2.39	39.41	20.8
	500 Year	1.88	39.41	20.8

Since the Flow Area and Top Width data remain consistent for all the above frequency discharges, the anaylsis for the worst case (highest velocity) only is deemed sufficient.

U.S. Army Corps of Engineers Procedure

This procedure is based on the U.S. Army Corps of Engineers' *Hydraulic Design of Flood Control Channels*, EM 1110-2-1601, July 1, 1991. The procedure is based on depth-averaged local velocity. The basic equation is:

$$D_{30} = S_f \; C_S \; C_V \; C_T \; d \; \{[(\gamma_w / (\gamma_s - \gamma_w)]^{1/2} \; [V / (K_1 \; g \; d)^{1/2}]\}^{2.5} \qquad \text{(Equation 3-3)}$$

where,

Variable	Variable Description	Overtopping	Q50	Notes
S_f	safety factor	1.2	1.2	
C_S	stability coefficient for incipient failure	0.375	0.375	0.375 for rounded, 0.30 for angular stone
C_V	vertical velocity distribution coefficient	1.0	1.0	= 1.283 - 0.2 log (R/W) for outside of bends (= 1 for R/W > 26)
R	center-line radius of bend	1000 m	1000 m	
W	water-surface width	20.8 m	20.8 m	main channel only
C_T	thickness coefficient	1.0	1.0	= 1 if thickness = $1D_{100}$ (or $1.5D_{50}$)
d	local depth of flow	2.78 m	2.78 m	from HEC-RAS at cross section 1288.5 BR
γ_w	unit weight of water	1000 kg/m^3	1000 kg/m^3	
γ_s	unit weight of stone	2643 kg/m^3	2643 kg/m^3	= 165 pcf
V	local depth-averaged velocity	2.18 m/s	2.5 m/s	from HEC-RAS at cross section 1288.5 BR
V_{ss}	design velocity	2.18 m/s	2.50 m/s	Use Local Velocity
K_1	side slope correction factor	0.6678	0.6678	Side Slope = 1.75:1 Repose angle Φ(°)= 41.8
g	gravitational constant	9.81 m/s^2	9.81 m/s^2	
D_{30}	**riprap size**	**0.13 m**	**0.18 m**	using Equation 3-3

Page 2-13 recommends that to maintain tranquil flow through curves in the watercourse the ratio of the curve radius to channel width be 3 or greater. Therefore,

	Overtopping	Q50	Notes
R/W =	48.1	48.1	> 3 for tranquil flow

R/W is greater than 3, thus, the flow is tranquil for Overtopping
R/W is greater than 3, thus, the flow is tranquil for Q50

Filter Layer Check
Pedestrian Bridge

Riprap Filter Design

The following design is based on a method presented in HEC-15(SI) and HEC-11(SI).

Granular Filter Blanket
HEC-15(SI) gives the following criteria for the design of a granular filter blanket:

$[(D_{15})_{surface} / (d_{85})_{subbase}] < 5 < [(D_{15})_{surface} / (d_{15})_{subbase}] < 40$ (Equation 11)

and,

$[(D_{50})_{surface} / (d_{50})_{subbase}] < 40$ (Equation 12)

Geotextile Filter
For a geotextile filter HEC-15(SI) recommends the following:

For $(d_{50})_{subbase} > 0.075$mm, use a geotextile with an AOS < 0.6mm.

For $(d_{50})_{subbase} < 0.075$mm, use a geotextile with an AOS < 0.297mm.

Surface Material =	Standard Riprap
Subbase =	Granular Fill

Granular Filter

$(D_{15})_{surface}$	=	100	mm
$(D_{50})_{surface}$	=	380	mm
$(d_{15})_{subbase}$	=	0.48	mm
$(d_{50})_{subbase}$	=	9	mm
$(d_{85})_{subbase}$	=	64	mm

$\frac{(D_{15})_{surface}}{(d_{85})_{subbase}} = 1.6$ **Filter satisfies design criteria from Equation 11.**

$\frac{(D_{15})_{surface}}{(d_{15})_{subbase}} = 208.3$ **Filter does not satisfy design criteria from Equation 11.**

$\frac{(D_{50})_{surface}}{(d_{50})_{subbase}} = 42.2$ **Filter does not satisfy design criteria from Equation 12.**

Geotextile Filter

(d50)subbase > 0.075mm, use a geotextile with an AOS < 0.6mm.

Filter Layer Check
Pedestrian Bridge

Subbase Filter Design

The following design is based on a method presented in HEC-15(SI) and HEC-11(SI).

Granular Filter Blanket
HEC-15(SI) gives the following criteria for the design of a granular filter blanket:

$[(D_{15})_{surface} / (d_{85})_{subbase}] < 5 < [(D_{15})_{surface} / (d_{15})_{subbase}] < 40$ (Equation 11)

and,

$[(D_{50})_{surface} / (d_{50})_{subbase}] < 40$ (Equation 12)

Geotextile Filter
For a geotextile filter HEC-15(SI) recommends the following:

For $(d_{50})_{subbase} > 0.075$mm, use a geotextile with an AOS < 0.6mm.

For $(d_{50})_{subbase} < 0.075$mm, use a geotextile with an AOS < 0.297mm.

Surface Material =	Granular Fill
Subbase =	Native Material

Granular Filter

$(D_{15})_{surface}$	=	0.48	mm
$(D_{50})_{surface}$	=	9	mm
$(d_{15})_{subbase}$	=	0.12	mm
$(d_{50})_{subbase}$	=	0.7	mm
$(d_{85})_{subbase}$	=	18.5	mm

$\frac{(D_{15})_{surface}}{(d_{85})_{subbase}} = 0.0$ **Filter satisfies design criteria from Equation 11.**

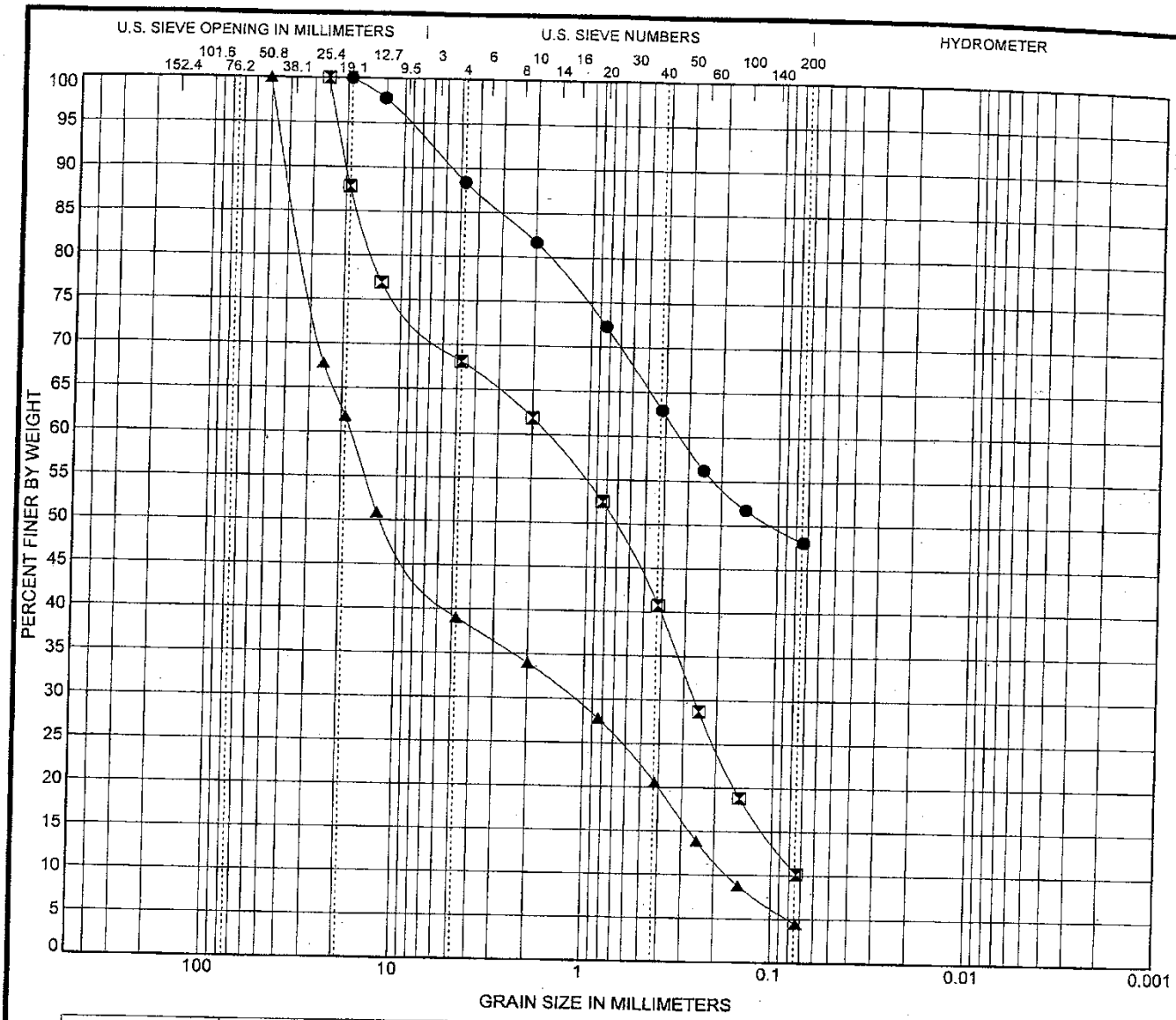
$\frac{(D_{15})_{surface}}{(d_{15})_{subbase}} = 4.0$ **Filter does not satisfy design criteria from Equation 11.**

$\frac{(D_{50})_{surface}}{(d_{50})_{subbase}} = 12.9$ **Filter satisfies design criteria from Equation 12.**

Geotextile Filter

(d50)subbase > 0.075mm, use a geotextile with an AOS < 0.6mm.

Soil Sample Analysis (Channel Bank)



	COBBLES	% GRAVEL			% SAND		% FINES	
		COARSE	MEDIUM	FINE	COARSE	FINE	% SILT	% CLAY
●	0.0	0.0	5.0	13.3	18.7	14.9	48.1	
⊠	0.0	0.0	25.7	12.4	21.1	30.6	10.2	
▲	0.0	32.2	20.4	13.4	13.4	16.0	4.5	

	Expl. No.	Sample No.	Depth (m)	LL	PL	PI	Water Content (%)	Cc	Cu
●	S4-2	D1	0.0-0.61				6.2		
⊠	S4-3	D1	0.0-0.61				6.3		
▲	S4-7	D2	1.52-2.13				4.9	0.44	106.24

	Sample Description
●	Coarse to fine SAND, some gravel, little silt - FILL
⊠	Coarse to fine SAND, little gravel, trace silt - FILL
▲	Coarse to fine GRAVEL, some sand, trace silt - FILL

Remarks:

HALEY & ALDRICH
Glastonbury, Connecticut

U.S. Interstate Route 84 Reconstruction
Waterbury, Connecticut
State Project No.: 151-273

GRAIN SIZE DISTRIBUTION

Date: 4/16/2001

File No.: 91313-100

CONN DOT SIEVE 91313SA.GPJ US_LAB.GDT 3/6/02

E. Del Priore DRILLER	SM - 001 - M REV. 1/94 BORING REPORT STATE OF CONNECTICUT DEPARTMENT OF TRANSPORTATION	Hole No. **S4-3**
P. Carrera INSPECTOR	TOWN: **Waterbury, CT**	Line & Station Offset
Haley & Aldrich, Inc. SOILS ENGINEER	PROJECT NAME: **Reconstruction of I-84** PROJECT NUMBER: **State: 151-273/H&A: 91313-102** BORING CONTRACTOR: **General Borings, Inc.**	N. Coordinate **230905.58** E. Coordinate **282461.88** **Berger, Lehman Associates, P.C.** PRIME DESIGNER

		Casing				Auger		Mud	Sampler		Core Barrel			
Surface Elevation: **106.73**	Utilized		X						X					X
Date Started: **21 November 2000**	Type	BW	NW	HW	Pipe	Solid	Hollow		SS		B(st)	B(dt)	NX(st)	NX(dt)
Date Finished:	Size I.D. (mm)	60	76	100	64				35	X	35	35	55	55
Groundwater Observations	Hammer (kg)	136	136	136	136			Bit	63.5		Type		Diamond	
@ **5.03** m after **0** hours	Fall (m)	0.6	0.6	0.6	0.6				0.76		of bit		Carbide	
@ m after hours														

DEPTH	Casing blows per half meter	SAMPLE DEPTH IN METERS FROM - TO	NO.	PEN. m	REC m	Type	BLOWS PER 0.15 METERS ON SAMPLER 0-0.15	0.15-0.30	0.30-0.45	0.45-0.60	STRATA CHANGE ELEV./DEPTH (m)	FIELD IDENTIFICATION OF SOIL REMARKS (INCL. COLOR, LOSS OF WASH WATER, ETC.)
		0.00-0.61	1	0.61	0.61	D	3	6	8	11		Medium dense brown coarse to fine SAND, little gravel, trace silt
											105.23	-FILL-
		1.52-2.13	2	0.61	0.45	D	17	20	25	28	1.50	Dense brown coarse to fine SAND, little fine gravel with cobbles
		3.05-3.35	3	0.30	0.00	D	29	100/0.15				No Recovery
5		4.57-4.72	4	0.15	0.15	D	100					Very dense brown medium to fine GRAVEL, some coarse to fine sand, trace silt with cobbles
											100.63	
		6.10-6.71	5	0.61	0.45	D	14	14	15	13	6.10	Medium dense brown coarse to fine SAND, trace silt Boulder from 7.7 m - 8.53 m
		7.62-7.70	6	0.08	0.00	D	100/.08					
10		9.14-9.45	7	0.31	0.15	D	31	100				Very dense brown coarse to fine SAND, some medium to fine gravel with cobbles
		10.67-10.82	8	0.15	0.15	D	100/.15					Very dense brown coarse to fine SAND and fine gravel, trace medium gravel
											94.54	-GLACIOFLUVIAL DEPOSITS-
		12.19-12.19	9	0.00	0.00	D	100/0				12.19	C1: Hard, fresh, gray and white coarse to fine grained granitic GNEISS. Foliation is moderately dipping, extremely close. Joints are moderately dipping to high angle, close to moderate, rough, undulating, fresh, open
		13.11-14.63	1	1.52	1.36	C		[RQD = 64%]				
15		14.63-16.15	2	1.52	1.52	C		[RQD = 64%]				C2: Same as C1 except joints are low to high

Casing Size	From	To	Meters of Earth	Rock
NW	0.0	13.11	13.11 m	3.04 m
			No. of Samples	
			9D,2C	

NOTES: **Bomb mounted Diedrich D-120 with wire winch to drive safety hammer. Borehole backfilled with drill cuttings upon completion.**

SAMPLE TYPE CODING: D=Driven C=Core A=Auger UP=Undisturbed Piston V=Vane Test SS=Split Spoon
PROPORTIONS USED: Trace=1-10% Little=10-20%, Some=20-35%, And=35-50%

Hole No. **S4-3**
Sheet **1** of **2**